New Scientist

WEEKLY 12 November 2022

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WHEN ARE YOU TRULY A GROWN-UP?

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THE NEW HUNT FOR ALIEN LIFE

How the James Webb telescope has changed everything

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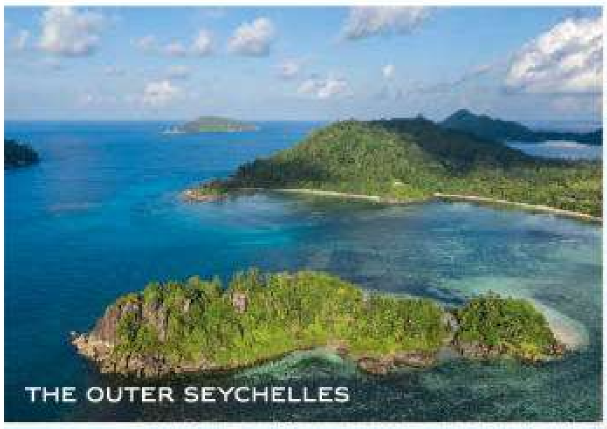
THE OUTER SEYCHELLES

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SYLVIA EARLE EXPLORES
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THERE ARE OVER 130
HOPE SPOTS GLOBALLY

SYLVIA EARLE WITH VOLUNTEERS,
THE OUTER SEYCHELLES

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ON OUR WATCH

Hope can now be spotted across all our planet's seas and oceans. Sites are made into aquatic havens by local communities, to safeguard the richness and diversity of the ecosystems they depend on. Sylvia Earle's invaluable experience as an explorer and marine biologist continues to help further their goal, through her organisation, Mission Blue. Together, they have created over 130 Hope Spots and counting. Carrying a message of hope for generations to come. It is that vision, that dedication to a perpetual planet, which we are proud to stand by. **For as long as it is needed.**

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OYSTER PERPETUAL ROLEX DEEPSEA

MISSION BLUE

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IN ITS COMMITMENT TO PROTECTING
30% OF THE OCEANS BY 2030

ROLEX

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Instant expert

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Podcast

Weekly

In a special episode, host Rowan Hooper visits Newlands Corner in the North Downs of southern England. This is the site of one of the world's oldest and most significant populations of wild yews, but the trees are now in decline, partly because of nitrate pollution. Rowan meets Geoff Monck of Treecosystems, who specialises in surveying and restoring arboreal ecosystems, to hear about how we might help.

newscientist.com/nspod

P. HORÃLEK/ESO

Stargazing Chile offers unrivalled views of the night sky

RICHARD RICKITT

Ball games Bumblebees seem to enjoy playing

Video

Bees at play

This week on our YouTube channel there is a chance to see buff-tailed bumblebees (*Bombus terrestris*) interacting with small wooden balls as part of a laboratory experiment. The insects repeatedly chose to roll the balls despite having no clear reward for doing so. This suggests they might simply enjoy moving these objects for fun, offering the first evidence of play in insects.

youtube.com/newscientist

Newsletter

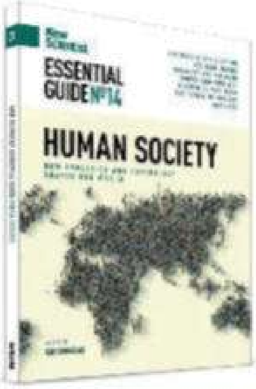
Fix the Planet

As environment reporter Madeleine Cuff heads to the COP27 climate summit in Egypt, she considers whether the COP process is working. While it is slow-moving, emissions are now predicted to peak in 2025 – which some think wouldn't have happened without the meetings.

newscientist.com/sign-up/fix-the-planet

Newsletter

> "If the COP process didn't exist, you would have to invent something like it"



Essential guide

How did evolution and psychology shape human society? We differ from most other animals in that we cooperate with strangers as well as with family members. Learn about how this happened – and the tensions it has created – in the latest *New Scientist Essential Guide*. Available to purchase now.

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Population paradox

Our planet is more crowded than ever, yet many must prepare for population decline

THERE are soon to be 8 billion of us and counting. Yet while the world's population is still growing fast overall, in many countries, the numbers are declining or will do soon.

Take the three largest. The population of China will begin to fall soon and could halve by 2100. India's will peak around 2050. And the US population would fall from the 2030s if not for immigration.

So there are two distinct issues to deal with: rapid population growth in some nations and population declines in others.

Many see limiting population growth as vital for tackling various environmental catastrophes unfolding around the world, as we report on page 14. Yet for wealthy Westerners to call for lower-income countries to control their populations simply in the name of protecting nature is hypocritical in the extreme, given that the rich have vastly larger environmental footprints. What's more, there is often more than a whiff of racism to such calls.

That said, there are good reasons for fast-growing countries to try to limit further population growth, as discussed on page 25, not least because rapid increases can lead to more poverty. What's more, two of the key factors in lowering fertility rates are educating women and respecting their rights, which all countries should be doing anyway.

> "Aside from a rise in immigration, there is no sure-fire way to stem nations' population decline"

Declining populations can be seen as a good thing in some ways – less pressure on wildlife, more space and so on. But having fewer working-age people and more older people is a huge economic challenge.

Apart from increasing immigration, there is no sure-fire way to stem individual nations' population decline. This means that, in many parts of the world, governments need to be readying care and pensions systems to cope with ageing populations.

These trends are highly predictable over the next few decades, so there is absolutely no excuse for failing to prepare. It is also hugely important to invest in health. An ageing population has much less impact if people remain healthy well into old age. ▮

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What goes on in Pakistan,
will not stay in Pakist

REUTERS/MOHAMED ABD EL GHANY

Pakistan's prime minister, Shehbaz Sharif, speaks to the media

Climate change

COP27 kicks off in Egypt

Funding to help vulnerable nations with the impacts of climate change is on the agenda for the first time, reports **Madeleine Cuff**

NEGOTIATORS at the COP27 climate summit in Egypt have agreed to discuss setting up a fund that could see higher-income countries pay reparations to vulnerable nations already struggling with the impacts of climate change. "Loss and damage", referring to the negative effects of climate change and efforts to minimise and address them, has been included in the formal conference agenda for the first time in the history of UN climate talks.

The talks opened with a stark message from UN secretary-general António Guterres, who warned that the world is "on a highway to climate hell" with its "foot on the accelerator".

Speaking on 7 November, just days after the UN warned that existing climate plans offer no "credible pathway" to limit global warming to 1.5°C, Guterres told delegates that the planet is "fast approaching tipping points that will make climate chaos irreversible".

Despite the challenges of rising inflation, escalating geopolitical tensions and an energy price crisis, he said the world must use the summit to forge a new "climate solidarity pact" that would see all countries contribute their fair share to emissions cuts. The world faces a choice between cooperation or a "collective suicide pact" caused by rising temperatures, he told delegates.

It was a sobering start to a summit that has seen more than 30,000 negotiators, journalists and campaigners travel to the resort of Sharm El Sheikh for two weeks of talks.

> **"How do companies make $200 billion in profits and not contribute to a loss and damage fund?"**

Funding is already emerging as a key battleground. Pakistan's prime minister, Shehbaz Sharif, said the provision of funding for countries affected was a matter of "climate justice". His country was hit by $30 billion of loss and damage as a result of devastating flooding earlier this year, he said at a press conference on 7 November. "Our journey to recovery will be held back by increasing public debt, rising global energy prices and no real access to adaptation finance," he said.

Barbados's prime minister, Mia Mottley, said it wasn't just up to governments to provide loss and damage funding, arguing that oil and gas companies should also contribute. "How do companies make $200 billion in profits in the last three months and not expect to contribute at least 10 cents in each dollar of profit to a loss and damage fund?" she said during a speech to world leaders.

Meanwhile, UK prime minister Rishi Sunak used his first appearance on the international stage to help launch a funding programme on 7 November to protect forests around the world. The Forests and Climate Leaders' Partnership aims to ensure that a pledge at the COP26 summit to halt and reverse global forest loss by 2030 is delivered.

The partnership will see member countries drive forward work on the deployment of carbon markets, community initiatives and other strategies for tackling deforestation needed to meet the 2030 goal. However, while 145 countries, representing more than 90 per cent of the world's forests, joined the COP26 pledge, just 26 nations, together responsible for one-third of the planet's forests, have so far joined the COP27 partnership.

Former US vice president Al Gore captured the palpable sense of frustration surrounding the summit over the gap between ambitious promises and real-world action. "We have a credibility problem – all of us – we are not doing enough," he told world leaders on 7 November. ■

Coronavirus

Lockdown impact on liver disease

The pandemic has seen a rise in deaths from liver disease and diabetes in England and Wales, perhaps due to problems accessing healthcare, reports **Jason Arunn Murugesu**

TOLGA AKMEN/AFP VIA GETTY IMAGES

An ambulance in January 2021, a period of high covid-19 cases in the UK

FAR more people have died from liver disease and diabetes in England and Wales since the coronavirus pandemic began than expected. Exactly why is unclear, but some deaths may be due to difficulties in accessing healthcare during periods of lockdown, along with rising alcohol consumption.

Between March 2020 and June 2022, there were 3834 excess deaths caused by cirrhosis and other liver diseases in England and Wales compared with the rolling five-year averages for these conditions, according to the UK Office for National Statistics (ONS). This is a 19.7 per cent rise on expected levels. Meanwhile, in the same period, there were 3466 excess deaths caused by diabetes – a 24.4 per cent rise.

The five-year averages exclude 2020 to discount the high mortality figures seen at the height of the pandemic, and the ONS only looked at the primary cause of death, so no deaths were counted twice.

"We know the vast majority of deaths due to liver disease result from alcohol-related liver disease," says Ian Rowe at the University of Leeds in the UK. "There was an increase in alcohol consumption in previously already heavy drinkers during the pandemic. It is very likely that this increased consumption has led to the increase in liver disease deaths seen over that period."

Deaths from liver disease between March 2020 and June 2022 rose higher above the five-year averages in women than in men – by 22.4 per cent compared with 18 per cent – although the cause isn't entirely clear. "It may be related to impacts of the pandemic that disproportionately affected women, but really we don't know," says Rowe. An ONS study found that women in the UK typically experienced lower life satisfaction and happiness than men during the pandemic.

Jagpreet Chhatwal at Harvard University says similar trends were seen in the US, with deaths from alcohol-related liver disease rising 22.4 per cent between 2019 and 2020. "It's not just the lockdowns that caused an increase in alcohol consumption, the lingering elevated stress in society is contributing to sustained increase in alcohol," he says. "Even a short-term increase in alcohol can result in chronic liver disease and associated mortality."

19.7%

Increase in liver disease deaths in England and Wales above five-year averages during the pandemic

24.4%

Increase in deaths caused by diabetes above five-year averages during the pandemic

The pandemic may have also led to later diagnoses of liver diseases, says Joanne Morling at the University of Nottingham, UK.

"We know that cirrhosis is often diagnosed late – almost 50 per cent of cases are first detected following an emergency presentation with end-stage cirrhosis, when survival is poor," she says. "If there is a true increase in the number of deaths during the pandemic period, it could relate to delays in diagnosis and late presentations related to reduced access to services."

Explanations for the excess diabetes deaths are less clear, says Jonathan Shaw at Monash University in Melbourne, Australia. One issue is that these deaths may be recorded differently depending on the doctor.

"For example, people with diabetes are known to be at increased risk of death from cardiovascular disease, but whether or not the doctor completing the death certificate for a person with diabetes who died of a heart attack actually attributes the death to diabetes is quite variable," says Shaw.

But he notes that the use of lockdowns is likely to have played a part. "This might be expected to adversely affect treatment of diabetes, so it might not be a surprise to see a rise in deaths in people with diabetes," he says.

> **"There was an increase in alcohol consumption in already heavy drinkers during the pandemic"**

In addition, Morling says that we don't know how many of the deaths involving diabetes during the pandemic also involved covid-19. "In the 50-plus group, it is likely to be related, as we know diabetes was a risk factor for covid-19," she says.

Some studies also suggest that covid-19 can sometimes cause diabetes. "But the evidence for this is still unclear, especially for type 1 diabetes," says Richard Oram at the University of Exeter in the UK.

Ultimately, the higher diabetes deaths are likely to be due to a combination of several of these factors, says Morling.

"Since the pandemic, the number of diabetics receiving all eight recommended health checks is increasing, with the NHS investing £36 million to help tackle health inequalities," says a spokesperson for the UK government's Department of Health and Social Care. It has also opened more than 80 community diagnostic centres in order to increase tests for liver disease, says the spokesperson. ▮

Technology

IBM quantum computer is the largest yet

Karmela Padavic-Callaghan

IBM's Osprey quantum computer has 433 qubits, or quantum bits, which is more than triple the size of the company's previously record-breaking 127-qubit computer.

Building Osprey was more challenging than just making more qubits, says Oliver Dial at IBM. Qubits can be disturbed by forces exerted on them by neighbouring qubits in a similar way to how "crossed wires" can make conventional computers malfunction. When more qubits are packed onto a chip, there are more chances for this to occur.

Qubits within Osprey are controlled by connecting the chip to conventional electronics. Dial says he and his team designed these connections to keep the qubits in check as precisely as they could. Since superconducting wires only work at temperatures close to absolute zero, Osprey must also be kept inside a fridge.

Researchers have high hopes for quantum computers because qubits, unlike conventional bits, can take on values of 0, 1 and, due to the oddness of quantum mechanics, a combination of both simultaneously. This should allow them to perform computations that are too complex even for state-of-the-art supercomputers, such as simulating chemical reactions in subatomic detail.

"Building Osprey was an exploration of how large of a quantum chip we can really manufacture. It taught us that we really can put over 400 qubits on a chip and get that to work. That was a huge lesson in engineering," says Dial.

IBM's team is on track to have a working quantum computer with 1121 qubits in 2023, he says. It is also developing a smaller chip that will test a new way of connecting qubits with the aim of mitigating errors. ▮

Analysis Environment

Does the UK need new nuclear plants to reach net zero?

With renewable costs plummeting, some academics argue new stations may not be needed, says **Madeleine Cuff**

EIGHT months ago, the UK government made a big bet on nuclear, promising to treble the size of the country's nuclear fleet between now and 2050.

Delivering on that promise would require huge investment in large-scale new nuclear plants and small-scale modular reactors, following years of delays.

Ministers said this push for nuclear was essential to achieve the UK's aim to have net-zero carbon emissions by 2050.

That future could now be in doubt. A government official told the BBC that plans for the Sizewell C nuclear power plant, which would supply around 7 per cent of the UK's electricity, are "under review" to cut spending. The prime minister's spokesperson later denied this, saying that funding negotiations were ongoing and the government "hoped to get a deal over the line as soon as possible".

However, some are questioning whether new nuclear is necessary.

For years it has been energy orthodoxy to argue that nuclear will be an essential component of the UK's energy mix to meet its net-zero goal. Wind and solar would supply most of the country's energy, but some back-up power would be needed for cloudy, non-windy days.

It is an argument broadly accepted by the UK government, the Climate Change Committee that advises it and campaigners.

But that is changing, says James Price at University College London, author of a study that suggests the government's backing for new nuclear is "increasingly difficult to justify".

Price and his colleagues used a model to design cost-effective net-zero energy systems for 2050, using any mix of technologies, such as nuclear fission and lithium batteries. The team ran the model 32 times with different variables, like weather, level of power supplies coming from Europe and the price of new nuclear power.

"Only in two cases did the model build any new nuclear power, beyond what we expect to still be running in 2050," says Price. Even then, it was on the assumption that nuclear could be delivered quickly and cheaply.

Renewables and storage technologies are becoming so competitive on price that they are crowding out new nuclear, he says. "Because renewables have got so cheap over the last decade people are struggling to catch up with that," he says.

For campaigners long opposed to new nuclear on the grounds it is a dangerous and polluting source of energy, Price's analysis is to be cheered. The argument for new nuclear is "getting increasingly hard to sustain, as the technologies or the enablers of a fully renewable system are becoming clearer and clearer", says Greenpeace UK's chief scientist Doug Parr.

7%

How much of the UK's electricity would be supplied by Sizewell C

It takes eight to 10 years to build a new nuclear power station. If models are saying a renewables-plus-storage system is feasible now, at current prices, they could well be by far the best choice in a decade's time, he says.

Simon Middleburgh at Bangor University, UK, disagrees with Price's study's conclusion. "There's just no reasonable future electricity supply which is net zero that doesn't include nuclear," he says.

What about nuclear fusion? This will be great if it works, but it is at least two decades away from becoming operational, says Amy Gandy at the University of Sheffield, UK

There is one point everyone who spoke to *New Scientist* agrees on. If the UK government ditches plans to build Sizewell C, it needs to have an alternative route to net zero. Without more large-scale new nuclear coming online, energy efficiency, renewables and storage will need extra backing. ▮

Sizewell in the UK is the proposed site of a new nuclear power station

MATTHEW HORWOOD/GETTY IMAGES

Zoology

Migration linked to bird 'divorce'

Break-ups are more common in bird species with longer migrations

Alice Klein

BIRDS that migrate long distances tend to be more likely than others to break up with their partner, according to an analysis of 232 species.

About 90 per cent of bird species are socially monogamous, meaning they form pairs that primarily breed with each other and raise offspring together. Some stay together for life, while others end up getting "divorced" and moving onto new partners.

To identify factors that lead to bird break-ups, Liu Yang at Sun Yat-sen University in China and his colleagues studied 232 species with documented divorce rates in one of the world's largest bird databases, Birds of the World.

They found that species that migrate particularly long distances to obtain food between breeding seasons typically have higher rates of splitting up (bioRxiv, doi.org/jkqk).

Great blue herons (*Ardea herodias*), for example, migrate more than 3000 kilometres and have a divorce rate of 100 per cent.

This may be because travelling further makes it harder for a pair to return home at the same time for their annual breeding season, says Gisela Kaplan at the University of New England in Armidale, Australia. One of them may get delayed by weather events like storms, she says.

"If you're the one who gets back first, it's risky waiting for your partner because you don't know if they'll show up – they may have died or been blown off course," says Kaplan. Finding a new partner may seem a safer bet even if it requires energy to go through courting again, she says. "Breeding seasons are often quite short so you don't want to miss out."

DANIEL BRUCE LACY/SHUTTERSTOCK

Great blue herons have long migrations and a high break-up rate

Anne Peters at Monash University in Melbourne says it makes sense for birds with long migrations to have higher divorce rates, but there are exceptions.

Black-tailed godwits (*Limosa limosa islandica*), for example, migrate more than 1000 kilometres from Iceland to the UK or south-west Europe each year but have relatively low divorce rates.

This seems to be thanks to an uncanny ability to synchronise with their partners, says Peters. Although members of a pair will follow separate migration paths and typically end up more than 900 kilometres away from each other, they are somehow able to return to their breeding ground in Iceland at almost the same time, which reduces the risk of break-ups, she says. "But most birds are not able to do that – it's a pretty amazing feat."

Other factors that have been found to lead to bird pairs splitting up include low breeding success, shyness in the male partner and climate change. ▮

Health

A daily aspirin dose raises risk of serious falls in older people

PEOPLE who are older than 70 may be more likely to have a serious fall if they take a low dose of aspirin every day, in a finding that may support more cautious prescribing when issuing the blood-thinning drug to those at risk of heart attacks and strokes.

As well as warding off cardiovascular complications, research suggests aspirin may slow cognitive decline and strengthen bones, a combination that would theoretically lead to fewer falls.

But results from the Aspirin in Reducing Events in the Elderly trial contradict that idea.

For an average of 4.6 years, Anna Barker at Monash University in Melbourne, Australia, and her colleagues followed 16,703 white Australian people, aged 70 or over, who were described as being "relatively healthy".

Half of the participants were assigned 100 milligrams of aspirin – a dose that is commonly prescribed to older people for the long term – to take once a day. The remainder had a placebo. Some of the participants took medication for other conditions, with this drug use being balanced between the aspirin and placebo groups.

During the study period, more than 1400 of the participants had at least one fall that required hospital care, says Barker.

People in the aspirin group were just under 10 per cent more likely to have such a fall, compared with those not taking aspirin (*JAMA Internal Medicine*, doi.org/jkm4). There was no difference in fracture risk between the two groups. It is unclear whether the same results apply to people of non-white ethnicities.

"We need to weigh up the risks and benefits with every medication that we add into the regime for an older person, and definitely we'd need to be very dubious about prescribing aspirin, knowing the increased risks that it brings with relation to serious falls," says Barker.

> **"We need to be very dubious about prescribing aspirin, knowing the increased risks it brings"**

The increase in serious falls in the aspirin group may be related to the drug's anticoagulant effect, says Jennifer Burns at the British Geriatrics Society. People who fall while taking aspirin may have considerable bleeding or bruising, prompting emergency care. Bleeding and bruising weren't assessed in the study.

Exercises to improve balance and fitness may more effectively reduce falls as people age, says Burns. ▮

Christa Lesté-Lasserre

Social media

Musk's Twitter takeover puts misinformation in the spotlight

Matthew Sparkes

RESULTS from a Twitter project aiming to tackle propaganda and misinformation were published just hours before Elon Musk's takeover of the company on 27 October, suggesting they may have been rushed out before the change at the top.

Twitter launched its Birdwatch project in January last year in an effort to stop the spread of misinformation in the US. The company recruits a small subset of users to label potentially misleading tweets and write notes that include additional context. These notes can then be chosen by an algorithm for display under the original tweet for US users.

For instance, a tweet claiming that a vaccine causes side effects could be placed in the context of a note that points to research showing that this is only the case for a fraction of those taking it. Such a claim doesn't necessarily violate Twitter's rules, which would trigger removal, so these notes aim to counter false or misleading claims.

> "The silence from people who work on Birdwatch leads me to believe that it might be in jeopardy"

Unlike some social media platforms that use simple up-and-down voting to raise or lower the visibility of content, Birdwatch uses a "bridging" ranking system that seeks to get feedback from people with a wide range of views in order to cancel out bias and "bridge" the gap between viewpoints. Notes are only shown under tweets if they are rated as helpful by enough people with different perspectives, from both ends of the political spectrum, based on their previous interactions with other content.

CARINA JOHANSEN/EPA-EFE/SHUTTERSTOCK

Elon Musk is planning to make changes at Twitter

In its first few months, the scheme was criticised for the poor accuracy of notes that were being promoted and for a lack of citations provided by contributors. But Twitter continued to tweak the tool and the report on the project shows that progress has been made.

Researchers at Twitter ran a survey in April that showed tweets picked up by the bridging algorithm to users who aren't Birdwatch contributors and, for some of those respondents, the notes attached to them. They found that 64 per cent of respondents who saw the notes alongside the tweets found them subjectively helpful.

On average, notes selected by the algorithm reduced the likelihood of agreeing with the substance of a potentially misleading tweet by about 26 per cent, and there were no statistically significant differences between people reporting as Republican or Democrat voters, suggesting that political bias wasn't an issue (arxiv.org/abs/2210.15723).

Alex Mahadevan at the Poynter Institute for Media Studies in Florida says seeing the report get rushed to a public release was "heartbreaking" because it highlighted that Birdwatch could be shut down.

"I think the silence from a lot of the people who work on Birdwatch now leads me to believe that it might be in jeopardy under the new ownership. It looks like they're reducing the number of human moderators who can put checks on misinformation," he says, referring to reports that content moderators at the company were being frozen out of the tools required to do their job. "If it goes away then there goes an opportunity to tackle misinformation in one of the least political and most palatable ways I think we have seen."

Musk didn't respond to a request for comment, but has tweeted that "Twitter needs to become by far the most accurate source of information about the world. That's our mission." He also tweeted that Birdwatch will be renamed Community Notes, and that the project has "incredible potential for improving information accuracy". Another of Musk's tweets, about Twitter's falling revenue, was subject to a Birdwatch note, offering a link to a news story on the topic.

Keith Coleman at Twitter, who has overseen Birdwatch since its launch, didn't respond to a request for comment but is understood to still be at the company. In a recent tweet he claimed that Twitter would continue recruiting new users to Birdwatch at a rate of 10 per cent growth a week. Twitter was contacted for comment, but no staff were available. ■

Green technology

Plant that turns CO_2 into methanol fuel is largest on Earth

Michael Le Page

THE world's largest facility for converting carbon dioxide and hydrogen into methanol is now up and running in China.

Methanol is used for the production of chemicals such as plastics and as a fuel. It is usually made from coal or natural gas, but making it from waste CO_2 will reduce greenhouse gas emissions.

"We estimate the emissions avoidance to be greater than 500,000 tonnes of CO_2 or equivalent per year," says Ómar Freyr Sigurbjörnsson at Carbon Recycling International (CRI), the Iceland-based company that developed the technology and designed the plant.

500,000

Tonnes of CO_2 emissions prevented per year by the new facility

This figure is based on estimates that producing a tonne of methanol from coal typically generates around 6 tonnes of CO_2 or equivalent, and also takes into account the emissions associated with the processes at the new plant.

The facility in the city of Anyang, run by a company called Shunli, combines CO_2 captured from emissions during the production of lime with hydrogen emitted when coal is heated to make coke for steel-making. It can turn 160,000 tonnes of CO_2 into 110,000 tonnes of methanol per year.

Previous demonstration set-ups for producing methanol from CO_2 have only been able to make around 5000 tonnes per year, so the Shunli plant is by far the largest to date. CRI describes it as the first commercial-scale facility.

CRI is already working on a second CO_2-to-methanol site in China, which will recycle CO_2 from a petrochemical complex to produce methanol for plastics production. ■

Environment

Computer chip emissions are rising

The environmental impact of Taiwan, the world's chip manufacturing hub, grows each year

Jeremy Hsu

THE environmental footprint of chip manufacturing is on the rise. Over the course of half a decade, Taiwan – where most of the world's high-tech chips are made – has seen increased greenhouse gas emissions, as well as electricity and water use, from its chip manufacturing companies.

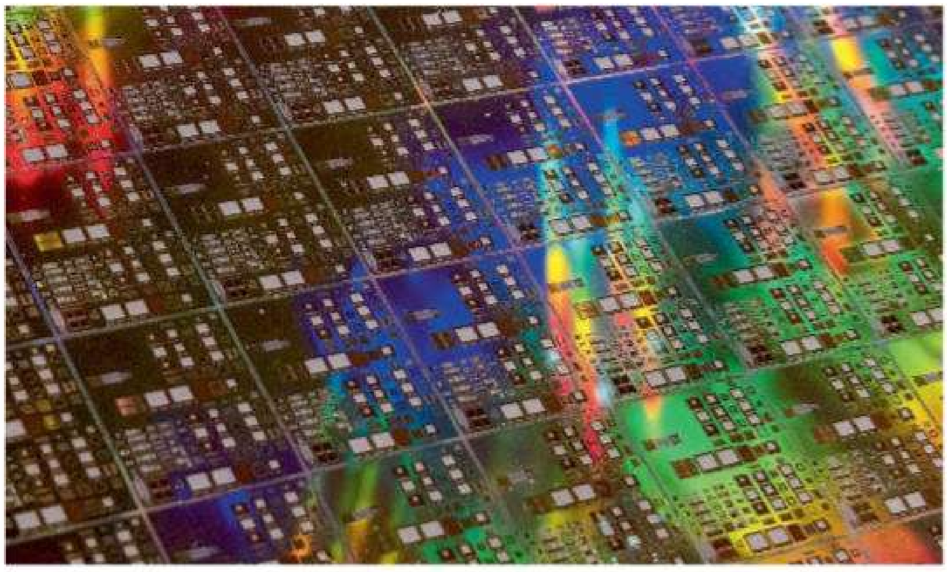
The world relies on Taiwan for computer chips found in everything from iPhones to automobiles. Chipmaking giant Taiwan Semiconductor Manufacturing Company (TSMC) provides about 90 per cent of the world's most advanced chips used in high-tech products, such as Apple and Sony devices.

Gauthier Roussilhe at the Royal Melbourne Institute of Technology in Australia and his colleagues analysed the corporate social responsibility reports for 16 chip manufacturers in Taiwan, including TSMC, from 2015 to 2020.

The team found that in this period, carbon emissions from chip manufacturing increased on average by 7.5 per cent each year, electricity consumption by almost 9 per cent per year and water usage by just over 6 per cent per year (arXiv, doi.org/jj6h). "You can see that just everything is growing," says Roussilhe.

The most probable reason for the increase is Taiwan having boosted chip manufacturing output to meet global demand. But another factor is that making more advanced chips requires energy-intensive equipment, such as extreme ultraviolet lithography machines that use 50 per cent more electricity than standard manufacturing techniques.

Silicon wafer at the Taiwan Semiconductor Research Institution



ANNABELLE CHIH/GETTY IMAGES

It is also particularly hard for manufacturers in Taiwan to switch to less carbon-intensive energy sources. Currently, renewables provide just 5.5 per cent of the country's electricity.

Chip manufacturing is responsible for around 12 per cent of Taiwan's annual greenhouse gas emissions – but that could reach between 15 and 37 per cent of the government-set emissions budget by 2050.

Reducing emissions will be tough unless Taiwan's government is willing to consider building more nuclear power plants, says Walter Den at Texas A&M University-San Antonio, who wasn't involved in the study.

At the moment, the emissions for chip manufacturing are effectively outsourced by many other countries to Taiwan. While the US and the EU are looking to boost domestic production, legislation slated to help doesn't talk about sustainability. "We were concerned not to see environmental considerations in there," says Thibault Pirson at the University of Louvain in Belgium, part of the team.

The researchers weren't able to include chip manufacturers based in the US or European Union in their study as none shared electricity or water usage for individual chip factories. "We need much more transparency if we want to assess the industry," says Roussilhe. ▮

Space

Graveyard star ate planets before Earth was even born

A STRANGELY cool star absorbed its planets billions of years before Earth even existed.

Last year, astronomers spotted a white dwarf star about 90 light years from us. White dwarfs are the remnants of stars that no longer carry out nuclear fusion, but this one, WD J2147-4035, seemed cooler than most. Its temperature indicated it was much older than other stars in its neighbourhood.

Now, Abbigail Elms at the University of Warwick, UK, and her colleagues have analysed more data for the star and confirmed its temperature, at around 3000 kelvin (about 2780°C), as well as detecting signs of elements that probably came from planets that once orbited it.

To do this, they used data from the European Space Agency's Gaia space telescope, the Dark Energy Survey and X-ray data. They estimate WD J2147-4035 is about 10.7 billion years old, and has been a white dwarf for 10.2 billion years. Earth is just 4.6 billion years old.

Elms and her team found sodium, lithium, potassium and possibly carbon in the spectral signature of the star's light. Levels of lithium and potassium were higher than those seen in other white dwarfs.

These elements are likely to have come from consuming planetary debris, say the researchers (arxiv.org/abs/2206.05258). But, when they modelled how this gave the star this chemical signature, they couldn't produce a scenario based on what we know about planets in our solar system that entirely explained the findings. "Something was going on in the early galaxy which we need to do some more analysis on," says Elms.

10.7bn

Estimated age of the star WD J2147-4035 in years

This shows us planetary systems were already forming when the Milky Way was young, says Andrew Swan at the University of Warwick, who wasn't involved in the study. "Not only that, but we learn what the planetary debris being eaten by these stars is made of: in one case it looks rather exotic." ▮

Alex Wilkins

Environment

US clock changes have deadly impact on deer and drivers

Matthew Sparkes

PERMANENTLY moving to daylight saving time in the US could prevent the deaths of 36,550 deer and 33 people there each year.

Calum Cunningham at the University of Washington in Seattle and his colleagues came up with the figures after analysing data from 23 US states on more than a million deer-vehicle collisions from 1994 to 2021. There are an estimated 2.1 million of these accidents in the US every year, killing about 440 people and causing upwards of $10 billion in damage.

The team found that the shift from daylight saving time to standard time in November, when the clocks go back an hour, led to an overall increase in the amount of driving during darkness. Collisions between deer and cars in the US also rose by 16 per cent in the week following this clock change (*Current Biology*, doi.org/gq58j5).

"The animals haven't changed their activity patterns at all. It's just there's more traffic on the roads in the periods that they're vulnerable," says Cunningham. "The change in time system causes sunset to come forward an additional hour, relative to clock time. That means that, irrespective of seasonal changes in day length, there is more traffic at night during standard time compared to if clocks remained on daylight saving time."

Deer collisions generally cause enough damage to vehicles that they are reported to insurance companies, making data easy to collect. Cunningham says that there is probably a similar trend with smaller mammals, but collisions with them are less likely to be recorded. This means the ecological benefit of scrapping time changes could be huge, he says.

But any such proposal would require a nuanced analysis of all of the ways time zones can affect society, he says. ▮

Analysis Autonomous weapons

Ukraine may have developed 'killer robots'

Comments from a Ukrainian military leader have sparked fears about a new kind of warfare, says **David Hambling**

UKRAINIAN PRESIDENCY/HANDOUT/ANADOLU AGENCY/GETTY IMAGES

Ukrainian president Volodymyr Zelenskyy and a Russian drone

UKRAINE has developed drones that are capable of finding targets autonomously, a Ukrainian military leader has claimed. This has raised the prospect that the ongoing war sparked by Russia's invasion of Ukraine could see the first confirmed use of "killer robots" in armed conflict.

Yaroslav Honchar, a lieutenant colonel in the Ukrainian military, gave details in an interview with Ukrainian news agency UNIAN last month. Honchar is co-founder of Aerorozvidka ("Aerial Intelligence"), a team of around a thousand volunteer drone enthusiasts and technologists set up in 2014 to develop and use drones and other technology.

Honchar claimed that the team's drones already fly scout missions autonomously and mentions the possibility of automated strikes, but didn't say such strikes had been carried out. "The technology already exists and this phenomenon cannot be stopped," said Honchar in the interview. Aerorozvidka declined to comment on the issue when contacted by *New Scientist*.

Ukraine has proven highly adept at using drones in innovative ways following Russia's invasion, from strikes by small multicopters armed with anti-tank bombs to a large-scale attack by multiple drones and robot boats against a Russian naval base in Crimea.

All of these have been under the command of human operators, but Ukrainian developers have previously described intelligent vision systems that allow drones to spot camouflaged military vehicles, which could easily be adapted for attacks without human assistance.

> "Ukraine is fighting for survival, so the military will use whatever tools can help them survive"

"I would not be at all surprised if the Ukrainians used some kind of machine-learning-based vision for automated target recognition in anti-tank roles, for example," says Mark Gubrud, a physicist and long-time campaigner against autonomous weapons. "That's where the times are at."

Both Russia and Ukraine are using radio-frequency jammers that block the communication between operator and drone. This may be driving the development of autonomous systems.

"Autonomy reduces the need for operator input, which reduces the effectiveness of jamming," says Zak Kallenborn at the Schar School of Policy and Government in Virginia.

Campaigners want new international laws to prevent such autonomous weapons being developed or deployed. On 21 October, 70 nations delivered a joint statement at the UN General Assembly calling for international prohibitions and regulations on autonomous weapons, but UN discussions have been taking place for years with little progress.

"There is no specific prohibition against the use of autonomous weapons. Any challenge to their use would have to be based on an argument that the weapons were indiscriminate and a threat to non-combatants," says Gubrud. "If their use is limited to materiel targets in areas of active combat, we're unlikely to see civilian casualties that substantiate such a charge."

"Ukraine is fighting for survival, so I would expect the military to use whatever tools can help them survive," says Kallenborn. "Potential Ukrainian use of AI-based autonomous weapons shows the urgency for the global community to establish rules of the road: what autonomous weapons are no big deal, and which need serious regulation and international bans."

Gubrud points out that using such weapons is likely to play badly with Ukraine's international allies and may not be needed. "Their success with using remotely operated systems shows that there is little need for full lethal autonomy," he says. ▮

Humans

Eight billion strong

As the global population hits new heights, what do our growing numbers mean for our health and the planet's, asks **Michael Le Page**

ON 15 November, the world will pass a major milestone, as the human population hits 8 billion for the first time. Of course, it is impossible to know exactly when we will reach this threshold, but the United Nations has chosen this date to mark the occasion, based on its modelling.

Coming just 11 years after the human population hit 7 billion, it might seem as if the number of people in the world is growing faster than ever. But, in fact, the growth rate is plummeting, with fertility rates now below replacement levels – the amount required to maintain a population – in most of the world.

In 2019, the UN forecast that the population would keep rising to 11 billion by 2100, but the medium scenario in its latest forecast is that it will peak in the 2080s. Two forecasts by the European Union's Joint Research Centre and the Institute for Health Metrics and Evaluation (IHME) in Seattle, Washington, predict the peak will come earlier, by 2070 (see diagram, below). This will be good news for efforts to limit climate change and the accelerating mass extinction of species.

But declining populations in many regions will bring new problems, and any environmental benefits will depend hugely on people's wealth and what they spend their money on.

While the link between the number of people alive on the planet and their impact on it is complex, there is no doubt that the growing human population is leaving ever less room for the rest of life on Earth. Three-quarters of all land and two-thirds of the oceans have already been significantly altered by people.

Humans now account for a third of the biomass of all land mammals, measured in terms of carbon content. Our livestock makes up almost all of the rest, with wild land mammals just 2 per cent. Similarly, the biomass of farmed birds is 30 times bigger than that of wild birds.

How many people can live sustainably on the planet? Estimates vary widely, but one 2020 study concluded our current food system can only feed 3 billion without breaching key planetary limits. Surprisingly, though, simply changing what we grow, and where, could raise this to nearly 8 billion. Reducing meat consumption and food waste could increase it to 10 billion.

> **"There is little doubt that the global population will grow to near 10 billion by 2050"**

Will we exceed this upper limit? There is little doubt that the population will grow to near 10 billion by 2050. "A lot of the growth is already baked in," says demographer Jennifer Sciubba at the Wilson Center, a think tank in Washington DC. "The future mothers are already born."

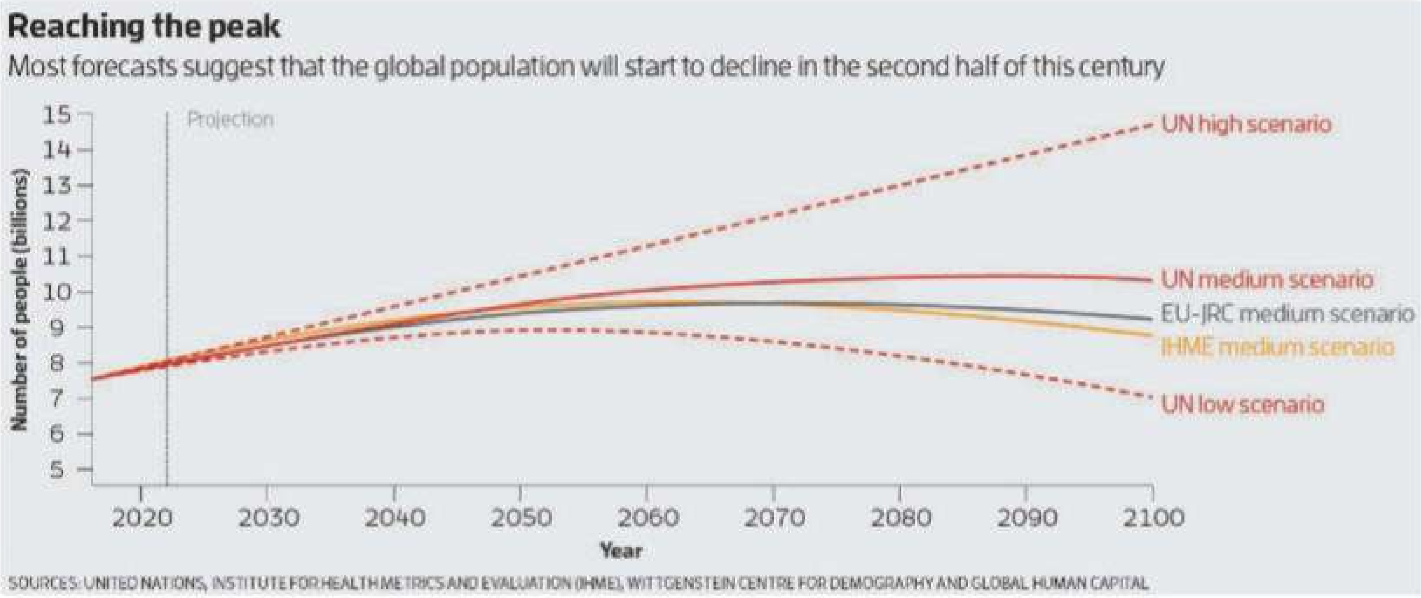
It is after 2050 that the uncertainty grows. Researchers agree that fertility rates will keep falling all around the world, but the UN sees them falling more slowly than others, says Stein Emil Vollset, who led the IHME forecast.

Two-thirds of the global population now live in places where the fertility rate – the average number of children per woman – has fallen below the replacement level according to the UN. Populations have already been declining in a number of countries with low fertility, including Japan, Italy, Greece and Portugal.

In places with a high proportion of young people, such as India, fertility falling below the replacement rate won't immediately lead to a declining population – there is a lag that can last many decades. But over the course of this century, more and more populations will decline. According to Vollset's forecast, for instance, the population of India will peak at 1.6 billion in 2049 and decline to 1.1 billion by 2100.

It is in parts of Africa, the Middle East and Asia where fertility rates remain well above replacement levels. Most population growth up to 2050 will happen in just eight countries, according to the UN's forecast: the Democratic Republic of the Congo, Egypt, Ethiopia, India, Nigeria, Pakistan, the Philippines and Tanzania.

Access to contraceptives is the fundamental reason behind falling fertility levels. Education and women's rights, including bans on child marriage, are also key. It is in places where education and rights for women and girls are lacking that fertility rates are highest.



Reaching the peak

Most forecasts suggest that the global population will start to decline in the second half of this century

SOURCES: UNITED NATIONS, INSTITUTE FOR HEALTH METRICS AND EVALUATION (IHME), WITTGENSTEIN CENTRE FOR DEMOGRAPHY AND GLOBAL HUMAN CAPITAL

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A crowded street of people in Istanbul, Turkey

FILADENDRON/GETTY IMAGES

Where women can choose how many children to have, many other factors also come into play. "Cost is a huge one," says Sciubba. In the UK, for instance, the cost of raising a child to age 18 is around £160,000, according to the Child Poverty Action Group.

Many people aim to have things like a good job, a stable relationship and a suitable home before having children, but may struggle to achieve this or find themselves unable to have as many children as they want by the time they do. Others don't want to have children and no longer feel compelled by social pressure to do so. Yet some are put off by pessimism about the future, says Sciubba.

For individual countries, rather than the world, another major factor is migration. Migration to wealthy nations has been preventing population declines in many such countries, but Sciubba doesn't think it will be allowed to increase enough to prevent these populations falling in the future. Less than 4 per cent of people worldwide move to other countries, she says, and that figure hasn't changed in decades.

While falling populations may be good from an environmental perspective, some economists and governments view them as a disaster. In most Western countries, working-age people pay for the pensions and care for those who are retired, so a rising proportion of older people causes serious financial strains. In other countries where relatives care for older people, the strain will be felt at the family level, says Sciubba.

But ageing populations don't necessarily spell economic disaster. Take Japan. "It's the oldest country on the planet, with a median age of 48, which has never happened before in all human history," says Sciubba. "And it still has a very strong economy."

The age level of populations is generally measured in terms of the ratio of people over 65 to those aged between 20 and 64, known as the dependency ratio. Japan has the highest dependency ratio in the world. But focusing on this metric alone is misleading, says Vegard Skirbekk at Columbia University in New York, author of *Decline and Prosper!*.

The impact of ageing also depends on the health of the population, he says. In the health-adjusted dependency ratios his team has calculated, Japan is average and it is mostly eastern European countries that score worst. "The solution is not to raise fertility, but to invest in health," says Skirbekk.

Some countries are, however, trying to raise fertility. For instance, China is facing a dramatic decline in its population, which is on course to halve to around 730 million by 2100, according to Vollset's forecast. This is why China is taking measures such as ending its one-child policy, but its efforts haven't been successful, says Vollset.

1.6bn

Forecasted peak of India's population, in 2049

Raising fertility is a lot harder than lowering it, he says. "From what we know about governments who try to influence fertility, they have been relatively successful when it comes to bringing fertility down, but it has proven to be much more difficult to increase fertility." What's more, even when policies do boost fertility, the effect tends to be short-lived, says Vollset.

The reasons for this are complex, but where, say, costs deter people from having bigger families, it requires substantial subsidies to make a difference. By contrast, inexpensive measures such as providing access to family planning and contraceptives, or promoting the benefits of smaller families, can have a big impact.

The enormous inertia in population growth also means it takes generations for policies to have an effect. "It's not something you can change quickly," says Skirbekk.

If efforts to boost fertility fail and the world's population does peak before 2100, any green benefits will depend on breaking the current correlation between people's wealth and their environmental footprints. The wealthiest 10 per cent of people are responsible for about half of all carbon emissions.

But there is a glimmer of hope here: carbon dioxide emissions per person have declined since 2012 and might continue to fall. Unfortunately, people are still eating more meat as they get wealthier. If nothing else changes, this will lead to continued habitat destruction and deforestation even after the world population peaks.

Or will the future be much wilder than we imagine? None of the population forecasts take climate change into account, and its impacts will become ever-more severe over the century. But given that future population growth is largely determined by those of us alive today, the big picture is unlikely to change much, says Sciubba. "It's not going to be radically different – unless you're talking apocalyptic." ▮

For another view on population, see page 25

Environment

Most ‘home compostable’ plastic doesn’t break down in garden bins

Madeleine Cuff

SHUTTERSTOCK/ANNA HOYCHUK

A compost bin containing scraps of food

MOST compostable plastics labelled as suitable for home composting don’t break down properly in garden bins, leaving scraps of residual plastic that can pollute garden soils and even enter the food chain.

The findings have prompted researchers to call for an overhaul of certification standards and have led at least one company to scrap the use of compostable plastics altogether.

More than 1600 members of the UK public took part in the Big Compost Experiment, a study to test how well compostable plastic packaging decomposes in home composting bins. They composted packaging such as newspaper and magazine wrappers, food caddy liners and shopping bags for three to 12 months, then sifted through the resulting compost to spot any remaining plastic.

Most of the items were judged to still be clearly visible to the naked eye, often in large, intact pieces. Only around one-third of them were reported as having fully composted, while some 60 per cent of certified “home compostable” plastics didn’t break down properly (*Frontiers in Sustainability*, doi.org/jj9j).

Danielle Purkiss at University College London says the results expose a major problem with existing certifications for “home compostable” packaging. These involve controlled lab tests that use a fixed type of compost, small swatches of packaging and specific microorganisms, she says.

But home composting conditions vary according to the type of compost bin used, the kinds of soil in the garden or allotment and where those doing the composting live.

“We’re showing that some of the underlying standards and testing to prove the performance of these materials – they don’t actually reflect the real world that they are going into,” she says. “And that’s a real red flag for us – it sort of means that, in fact, standards and certification aren’t fit for purpose.” Purkiss also worries about plastic residues in compost getting into the food chain if it used to grow produce.

Compostable plastics have surged in popularity as brands seek sustainable alternatives to traditional packaging. But most compostable plastic ends up being burned or sent to landfill in the UK because there is no dedicated collection route to take the waste to industrial composters.

> **“The testing for certification doesn’t actually reflect the real world that the materials are going into”**

David Newman from the Bio-based and Biodegradable Industries Association, which represents producers of biodegradable and compostable packaging, says many people who make compost at home aren’t doing it properly, and it would be better to route compostable packaging into industrial composting. “The moral of the story is we need to sort out our food waste collection systems,” he says. ▮

Technology

Unpiloted military helicopter flies in simulated mission

A US military helicopter controlled entirely by a flight computer flew low and fast through a valley during a 134-kilometre test run to deliver blood supplies. A separate test flight showed how the autonomous version of a Black Hawk helicopter could also hoist more than a tonne of cargo slung beneath its belly and even change flight paths to pick up a mannequin standing in for a wounded soldier.

“It’s a truly autonomous system,” said Igor Cherepinsky at Sikorsky Innovations, the aircraft manufacturer that produces the Black Hawk, at a press conference. “You don’t even need a data link – the aircraft makes all the decisions.”

This was the latest milestone in a US Defense Advanced Research Projects Agency program called ALIAS that is testing Sikorsky’s MATRIX technology – a drop-in kit that can convert helicopters into aircraft that fly autonomously. The flight demonstrations took place during an exercise in October.

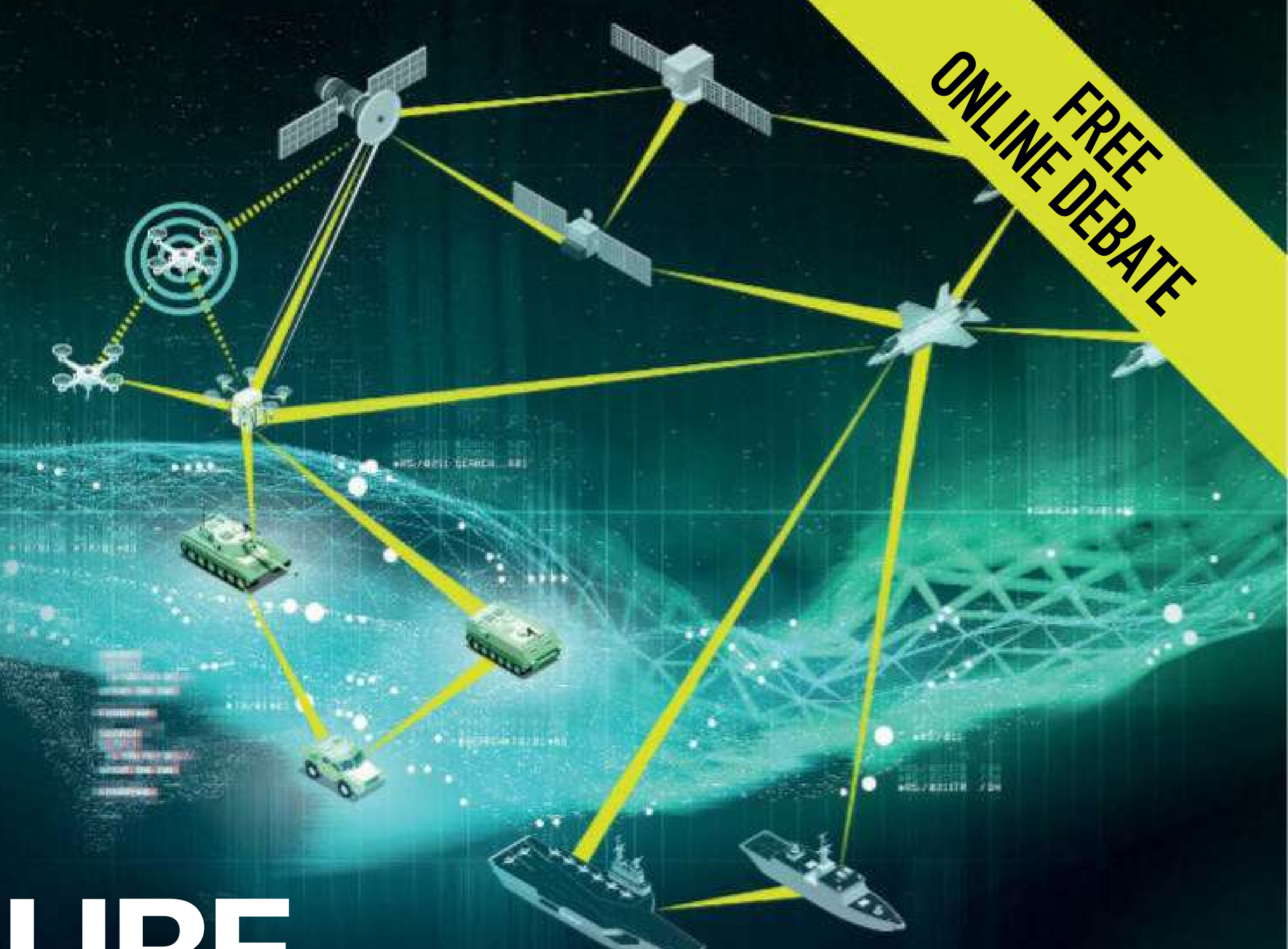
TED CARLSON/SIKORSKY AIRCRAFT

A Black Hawk helicopter flying autonomously with a tonne of cargo attached to a sling

“I think it’s a significant jump from the prior exercises and experiments where there was still a pilot onboard,” says Stacie Pettyjohn at the Center for New American Security, a national security think tank in Washington DC. “Eighty miles is a pretty significant distance.”

The autonomous Black Hawks may steer clear of some prior controversies involving autonomous military vehicles because they aren’t armed with weapons. But there is always a risk that such autonomous aircraft, even those without weapons, could harm people on the ground if something goes wrong, says Pettyjohn. ▮

Jeremy Hsu



New Scientist
Debate

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THE FUTURE OF CONFLICT

How advanced technology, a changing geopolitical landscape and the war in Ukraine are shaping the future of conflict

Wednesday 23 November 2022 7-8pm GMT | 2-3pm EST and on demand

In 2021, the UK government set out its vision for Britain's security, defence and foreign policy in a major Integrated Review designed to strengthen the country's resilience to threats from home and abroad, to shape the UK as a science and technology superpower and place climate change at the top of its international priorities.

Since then, the world has changed. Russia's invasion of Ukraine has challenged the conventional view on how a war in Europe should be fought. Join us to hear the answers to the key questions including:

- **What does this mean for Britain's armed forces and the skills and technologies they will need to protect us?**
- **Where does it leave Britain's plans to become a science and technology superpower?**
- **How should Britain's spending priorities change?**

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Space

Strange, shrouded galaxy is blasting out cosmic neutrinos

Leah Crane

THE IceCube Neutrino Observatory in Antarctica has found a second source for high-energy neutrinos from outer space. These particles are notoriously hard to spot and even harder to trace back to their sources, but they perfuse the entire universe. This finding gives a better understanding of where they form.

The IceCube researchers, led by Francis Halzen at the University of Wisconsin-Madison, found their first definitive source for a single high-energy cosmic neutrino in 2017: a blazar called TXS 0506+056 blasting a huge jet of energy towards Earth. An updated method to analyse nearly a decade's worth of data let the team find its second neutrino source, called NGC 1068. The researchers traced 79 high-energy neutrinos back to this relatively nearby galaxy (*Science*, doi.org/gq6g8b).

"When we first published these 10 years of data, NCG 1068 was there, but we were not sure if it was a background fluctuation or if it was a real source," says Halzen. "Now, we know these are not fluctuations."

Cosmic neutrinos are produced when a proton slams into another particle, creating a shower of fundamental particles, some of which later decay and release neutrinos. NGC 1068 seems like a near-perfect environment for this to happen. It is an active galaxy, meaning its central supermassive black hole is gobbling up material and creating powerful radiation as it does so. But its centre is shrouded in a dense knot of gas and dust, which obscures the black hole while giving the radiation something to slam into in order to produce neutrinos.

There are far more active galaxies like this one than there are blazars similar to TXS 0506+056, so this finding might help explain why there are so many cosmic neutrinos floating around the universe. ▮

Reproductive health

Abortions are increasing in US states where it is still legal

Grace Wade

SAFE ABORTION IS A HUMAN RIGHT!

ROBERTO SCHMIDT/AFP VIA GETTY IMAGES

The Women's March rally in Washington DC on 8 October

SINCE the US Supreme Court overturned the right to abortion, the number of abortions performed in the US has declined. However, in states where the procedure remains legal, abortions have increased by just over 11 per cent.

In June, the US Supreme Court overturned Roe v Wade, the landmark ruling that protected the right to abortion for nearly 50 years. Since then, 13 states have banned abortion and five have severely restricted it. An additional 10 states have bans that are currently being challenged in state courts.

Ushma Upadhyay at the University of California, San Francisco, and her colleagues analysed data on the number of abortions performed in the US between April 2022, two months before the court's decision, and August 2022. Abortion numbers before that period had been generally increasing since 2017.

Nearly 80 per cent of abortion providers agreed to disclose how many abortions they performed each month to the researchers for their analysis, representing an estimated 82 per cent of all US abortions.

The team found that the number of abortions nationwide declined by 6 per cent in the analysis period, but increased by 11 per cent in states with minimal restrictions on the procedure (Society of Family Planning report, doi.org/jj58).

11%

Increase in abortions in US states where it is still legal

The increase is probably due to an influx of people travelling from states where abortion is banned to access care, says Upadhyay. "We knew people would have to travel [out-of-state] for an abortion, but we didn't know just how many would be unable to make trip."

The central southern region of the US, which includes Texas and Alabama, saw the greatest reductions in abortions – a 96 per cent decrease. In that region, abortions can still occur to save the life of the parent. The western Midwest, which includes Kansas and Minnesota, had the greatest increase in abortions at about 12 per cent.

In another recent study, Upadhyay and her colleagues used census data to calculate the average time it takes for women of reproductive age in the US to reach the nearest abortion clinic. They found that since Roe was overturned, the average travel time has increased from about 28 minutes to over 100 minutes. Black, Indigenous and other people of colour had the greatest increases in travel time to abortion facilities (*JAMA*, doi.org/jj59). Travelling long distances for an abortion is impossible for many people, says Upadhyay, particularly those who can't take much time off work or who must care for small children.

These people may have to rely on non-profit organisations that provide abortion medications, which can pose legal risks, says Rachel Jones at the Guttmacher Institute, a reproductive health organisation in New York City.

A recent meta-analysis of 36 studies found that, compared with planned pregnancies, unintended pregnancies are associated with higher rates of prepartum and postpartum depression and domestic violence. Babies from unintended pregnancies are also more likely to be born preterm or with low birth weight (*JAMA*, doi.org/jj6b).

"When someone wants to have an abortion, but is unable to get one, the impact on their lives can be devastating," says Upadhyay. ▮

Music

Phantom notes played by violins turn out to be real

Karmela Padavic-Callaghan

A MUSICAL sound once thought to be heard only in our heads as a quirk of the ear canal is actually real. Violins can produce these unusual tones – and higher quality instruments can produce them more strongly.

In 1714, Italian violinist Giuseppe Tartini discovered that, when playing two notes simultaneously, he unexpectedly heard a third sound. This third note was later named a combination tone because it is a blend of the frequencies of the two original tones. It was thought that these tones arose entirely in our ears, due to the way sound is amplified by the cochlea, rather than actually emanating from an instrument.

Giovanni Cecchi at the University of Florence in Italy and his colleagues decided to investigate how different violins produce combination tones. They recorded a professional violinist playing selected pairs of notes on five violins and used a computer to decompose the sound waves.

PEH ALEXANDRE/EYEEM/ALAMY

Violins can produce seemingly 'phantom' notes

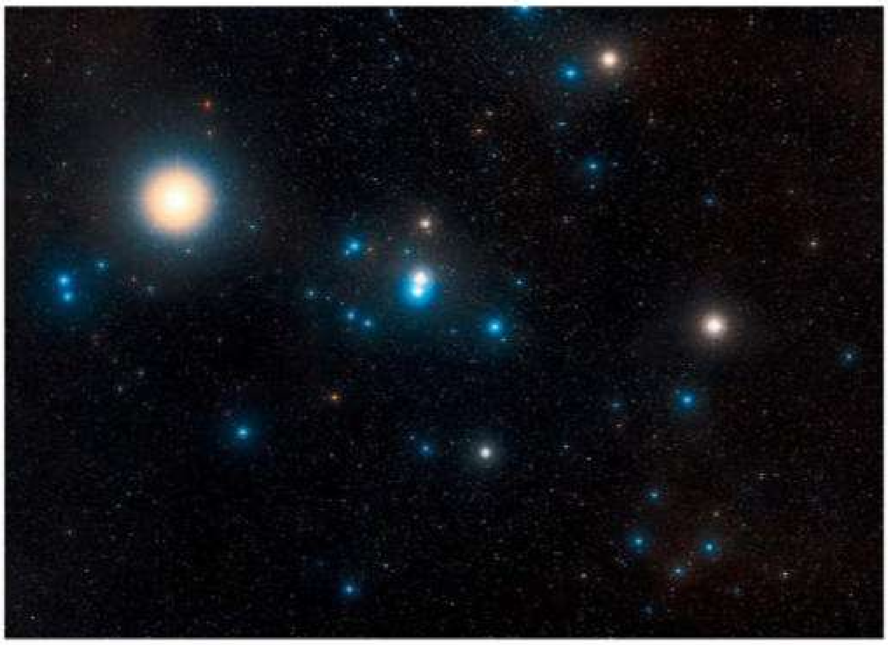
They found that all the violins produced combination tones, but the ones produced by a vintage, high-quality violin were about 75 per cent louder than those from a modern, mass-produced instrument (*The Journal of the Acoustical Society of America*, doi.org/gq53b8).

The researchers now want to study more violins to pinpoint exactly which part of the instrument is responsible for the combination tones, says Cecchi.

Astronomy

Crooked star clusters may signal Einstein was wrong

Leah Crane



NASA, ESA, AND STSCI.

The distribution of stars in the Hyades cluster is lopsided

A STRANGE effect in clusters of stars is bringing our ideas of how gravity works into question. These star clusters seem to have an unexpected asymmetry, which fits better under an alternative theory of gravity called modified Newtonian dynamics (MOND) than under Albert Einstein's widely accepted theories.

Clusters of stars, which orbit the centre of their galaxy, typically look a bit like a two-armed pinwheel with opposing tails – though they don't spin. The tails are formed when stars bouncing around in the cluster begin to travel either slightly faster or slower than the cluster as a whole. The leading tail is made up of stars that are slightly closer to the galaxy's centre and the trailing one is made of stars that are slightly further from the galactic centre and that fall behind.

In standard, or Newtonian, gravity, we would expect the two tails to be roughly equal: as stars bounce around within the cluster, they should be equally likely to end up in either tail. But when Pavel Kroupa at the University of Bonn in Germany and his colleagues examined three stellar clusters, they found that wasn't true. The leading tails all had more stars than the trailing ones. Simulations showed that this asymmetry was a better match to the predictions of MOND than those of Einstein's general relativity (*Monthly Notices of the Royal Astronomical Society*, doi.org/gq4trz).

"It's like there are two doors to escape the cluster, and the stars can only pass through the doors if they have the right direction and the right energy – otherwise they will just bounce around within the cluster," says Kroupa. "In MOND, the front door is simply bigger."

50%

Decrease in the lifetime of a star cluster under modified gravity

Because of the way that gravitational effects compound with one another in MOND, the forces pulling stars towards the centre of the galaxy, and therefore towards the leading tail, are stronger than in Newtonian gravity.

In the simulations, this had broader effects for entire clusters. More stars bouncing to the leading tail made the cluster spin and slow down. Eventually, the clusters fell apart. Under MOND, the clusters had lifetimes between 20 and 50 per cent of those experiencing Newtonian gravity. This would roughly match what astronomers have observed, says Kroupa.

But with only a few clusters tested for this effect, it isn't yet time to bin Newtonian gravity. "It's somewhat promising, but it does not provide completely definitive evidence for MOND," says Indranil Banik at the University of St Andrews, UK. "This asymmetry does make more sense in MOND, but in any individual cluster there could be other effects that are causing it – it's a bit unlikely that would happen in all of them, though."

To show that this asymmetry is caused by MOND, we will have to observe many more star clusters in detail, and it will have to pass other cosmic tests as well. Many cosmologists are sceptical of MOND, partly because it doesn't seem to fit with observations of the universe on the largest scales and partly because of the huge consequences if it is real.

"If MOND is correct, then all calculations regarding galaxies, galaxy formation, galaxy interaction and much of the whole universe are completely wrong," says Kroupa. "We would have to reset – reinvent cosmology, basically." The evidence required to do that would be more than a few crooked clusters.

Biology

Cane toads fling their tongues so hard the recoil slaps their heart

Jake Buehler

CANE TOADS practically lick their hearts as they eat. Their tongues stretch further down their throats than they extend to catch prey.

Many frog species have powerfully sticky tongues that yank prey into their mouths. The muscular and skeletal dance that allows a frog's tongue to extend and ensnare prey is relatively well-understood, says David Blackburn at the University of Florida. "But we actually know nothing about what happens to the inside of a frog when it closes its mouth," he says.

To get an inside look, Blackburn and his colleagues studied cane toads (*Rhinella marina*) using XROMM analysis, a 3D X-ray video technique for tracking the fast movements of bones and cartilage.

In three toads, the team surgically implanted nearly two dozen small tantalum markers in the skull, jaw, tongue, chest bones and hyoid apparatus – a cartilaginous sling shaped like a shallow dish that supports the tongue and throat muscles. The team noted how the markers moved as the toads fed on crickets in the lab (*Integrative Organismal Biology*, doi.org/jj7j).

The first glimpses of the footage were a shock. After the toad's mouth shut, the team saw the tongue recoil deep down the throat.

"We thought something was wrong with the videos," says Rachel Keeffe at Mount Holyoke College in Massachusetts. "We thought that we didn't do something correctly, because we were like 'there's no way this tongue marker is actually behind the back of the skull'."

> "We thought, 'there's no way this tongue is actually behind the back of the toad's skull'"

As the toad pulls its tongue back into its mouth, the hyoid – which sits below the tongue and between the oesophagus and the front of the neck – jerks backwards and down, sliding along the length of the oesophagus. Once it slips further than the back of the toad's head, the tongue tip races down the throat and intercepts the now flexed and cup-like basin of the hyoid as it presses up into the wall of the oesophagus. Blackburn likens it to a baseball slapping into a glove.

On average, the tongue stretches further back into the body than it does forwards to snag prey. "It looks like it would hurt," says Keeffe. "[The tongue is] coming back so far."

The tongue and hyoid manage to bump into the heart, which sits just behind the toad's chest bones, past the animal's extremely short neck. The organ is spared direct contact thanks to a wall of tissue. ▮

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Space

Weird dead star may have a solid surface

A STRANGE star about 13,000 light years away may have a solid surface, not a gaseous one like most stars. The star, called 4U 0142+61, is a magnetar – the dense, highly magnetised corpse of a star that exploded in a supernova.

Roberto Turolla at the University of Padova in Italy and his colleagues examined X-rays from the magnetar, which suggest it may have a solid surface (*Science*, doi.org/jj93). Because of the extreme gravity, they think the star's surface is most likely to be made from a material called a Bingham plastic, which is between a solid and a fluid – mayonnaise is a common example. It is probably made of strange crystals of iron and other heavy elements, their atoms stretched into cigar shapes by the powerful magnetic fields, says Turolla. **Leah Crane**

BSIP SA/ALAMY

Geology

Tonga eruption hit the mesosphere

THE giant plume of ash, gases and water ejected by the Hunga Tonga-Hunga Ha'apai volcano during its eruption in January was so tall it entered the mesosphere, satellite data has confirmed.

The volcanic plume was 57.5 kilometres high at its peak, the highest ever recorded. It entered the mesosphere – which sits above the stratosphere – twice, once at 0430 UTC on 15 January, and again at 0450 UTC the same day (*Science*, doi.org/jj96).

Simon Proud at the University of Oxford and his colleagues used satellite data and the parallax effect, where the location of objects can shift according to where they are viewed from, to calculate the plume's exact height.

Volcanic eruptions that reach the mesosphere are rare, and this is the first time one has been confirmed. **Madeleine Cuff**

Health

Invasive mosquito seen in Ethiopian malaria cases

AN INVASIVE species of mosquito from Asia has been linked to a malaria outbreak in Ethiopia. Its spread could make it harder to eradicate malaria, which kills around 627,000 people each year.

Most malaria infections in Africa are spread through the mosquito *Anopheles gambiae*, but *Anopheles stephensi* (pictured) has taken a foothold on the continent's east coast. *A. stephensi* was first confirmed in Djibouti in 2012 and has since spread to Ethiopia, Sudan, Somalia, Yemen and Nigeria.

In spring 2022, the city of Dire Dawa in Ethiopia saw an increase in malaria from around 200 cases per year to around 2400 cases, says Fitsum Tadesse at Armauer Hansen Research Institute in Ethiopia.

When residents sought medical care for malaria at local clinics, Tadesse and his team looked for mosquitoes within a 100-metre radius of each household. Around 97 per cent of the mosquitoes the team found were *A. stephensi*.

People living in households with water storage containers, where the insects could lay eggs, were more than three times as likely to test positive for malaria than those without. Tadesse presented these results at a meeting of the American Society of Tropical Medicine and Hygiene in Seattle on 1 November.

Because *A. stephensi* prefers to lay eggs in residents' water storage containers, it can persist throughout the dry season. "Instead of two or three months, [malaria season] will be 12 months a year," says Ayman Ahmen at the University of Khartoum in Sudan. Without significant investment in preventing the insects' spread, says Ahmen, "catastrophe is coming". **Corryn Wetzel**

Really brief

REUTERS/STEVE NESIUS

Falcon Heavy rocket launches satellites

SpaceX's enormous Falcon Heavy rocket has launched for the fourth time, carrying two secretive satellites from the US Space Force into high orbits. It is the most powerful rocket in use today, and because of this, it can shuttle satellites into orbits that other operational rockets can't reach.

Phones detect if bridges will fail

The accelerometers in our smartphones collect information as we travel over bridges, and this can reveal if the structures are weakening. Using such data to inform when they should be serviced could add nearly 15 years of life to a new bridge (*Communications Engineering*, doi.org/jj9h).

Whales may ingest microplastics

Blue whales could be eating 10 million pieces of microplastic a day. High microplastic concentrations have been found 50 to 250 metres under the ocean's surface, where filter-feeding whales often target krill. Little is known about how this may affect health (*Nature Communications*, doi.org/jj9g).

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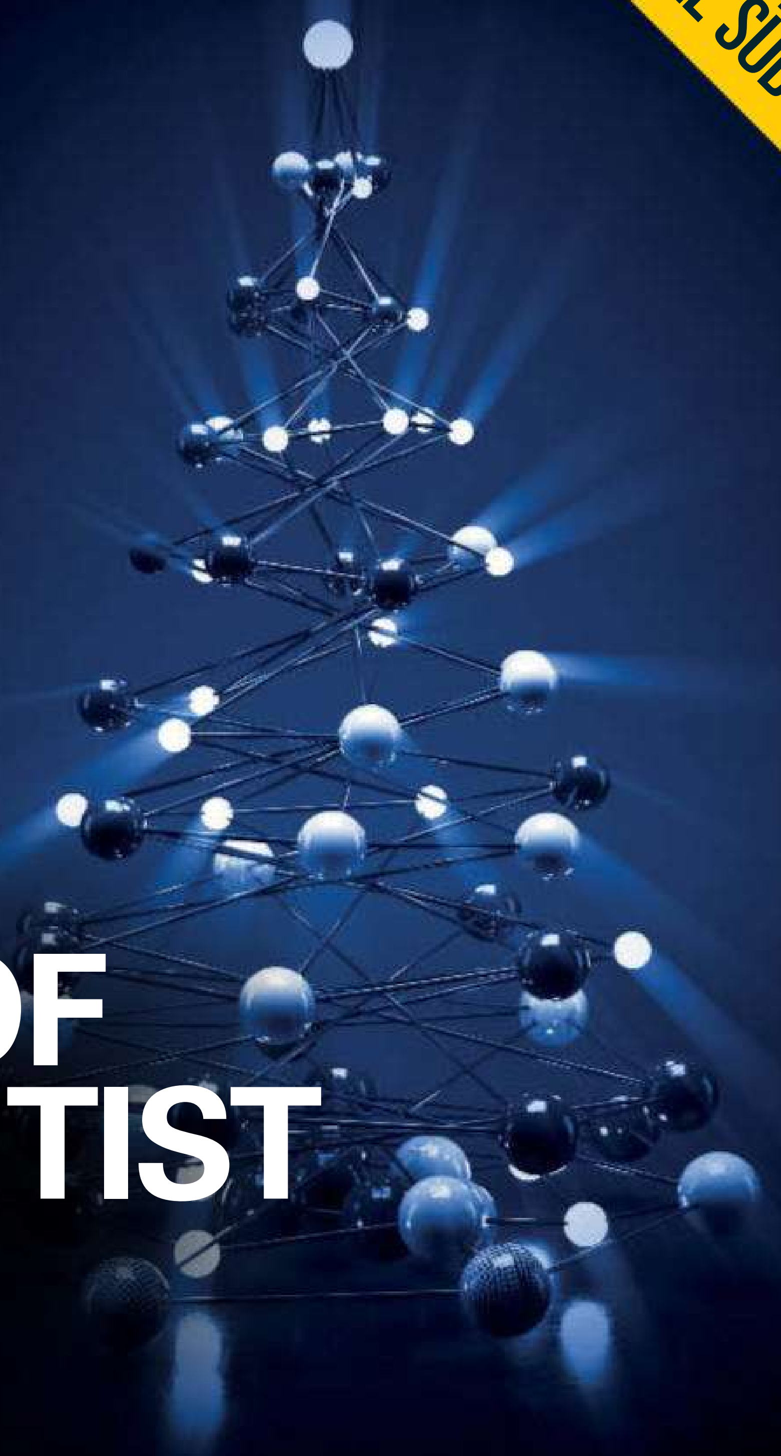

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Comment

A planet full of people

The 8 billionth person will be born next week. Tackling population growth is key to fighting climate change, says **Robin Maynard**

AS THE world desperately looks to COP27 for solutions to the climate crisis, on 15 November – in the very midst of the conference – the UN will symbolically mark the point when our global population reaches 8 billion people. The timing may be a coincidence, but the two are undeniably connected.

Earlier this year, a key report from the UN's Intergovernmental Panel on Climate Change unequivocally stated: "Globally, Gross Domestic Product (GDP) per capita and population growth remained the strongest drivers of CO_2 emissions from fossil fuel combustion in the last decade." Unsurprisingly, then, a major study into climate solutions called Project Drawdown ranked "family planning and education" – two critical factors in lowering fertility rates and population growth – as the third most effective climate solution in limiting warming to 2°C by 2100, and the seventh most effective in limiting warming to 1.5°C, with potential CO_2 savings of 68.9 gigatonnes by 2050.

This shouldn't be a surprise. Every climate change mitigation measure we employ will bring greater gains when contending with the emissions of fewer people overall. Population action is one essential pathway, but isn't alone.

MICHELLE D'URBANO

The average UK person produces 10 times the CO_2 of someone living in Benin. The world's richest 1 per cent of people produce double the emissions of the 50 per cent of the world's citizens who fall into the lowest income level – with the top 10 per cent producing around half of total emissions. A closer perspective is required, however. Grotesque as the inequity is, the top 1 per cent only contribute a sixth of emissions, and those in the top 10 per cent aren't all plutocrats, but those earning more than €37,200 (£32,400). Cutting overconsumption and tackling inequality is morally and environmentally essential – but it isn't enough.

Population growth traps people in poverty. In some of the world's lowest-income countries, population growth has seen the actual number of people living in poverty increase, despite a reduction in the proportion of those affected. Investing in reproductive health and ensuring greater access to family planning will help combat climate change and both tackle inequalities and address the population growth that contributes to inequality.

So why is population so rarely discussed in this context? There have been some hideous examples of governments using it as a proxy for state suppression and control, but, as the UN confirms, most population policies haven't been coercive. Commentators default to those negative past policies, ignoring or unaware of the many examples – from Thailand to Costa Rica – of policies such as investment in family planning that prioritised human rights and women's choice, while also slowing population growth.

This really matters because the numbers involved are staggering. A seemingly small change, such as people on average having "half a child" fewer, would have a profound, positive impact on people and planet.

While the UN's median projection is for an additional 2.4 billion people by 2100, it also recognises the possibility of a population lower than today's by the end of the century (see page 14). Investment in family planning, gender equality and education fundamentally improves people's lives, particularly those of women and girls, and helps bring all the advantages of ending and reversing population growth. Tackling climate change demands some tough choices – so why wouldn't we also make the easy decisions that support positive solutions?

When the 8 billionth person is born on 15 November, let's invest in measures that will give them the best chance of a long and decent life on a healthy planet. ▮

Robin Maynard is executive director at Population Matters, a writer and a campaigner

This changes everything

Goodbye to the singularity

Cyberpunk, once a glittering vision of the future, now feels passe. *The Peripheral* gives a new outlook on how tech could transform humanity, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Future of Another Timeline* and they are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

Annalee's week

What I'm reading

Economist Brad DeLong's epic tale of wealth and democracy, Slouching Towards Utopia: An economic history of the twentieth century

What I'm watching

I mean, The Peripheral, *obviously*

What I'm working on

A story about long-termism

This column appears monthly.

I WAS watching the new series based on William Gibson's 2014 sci-fi novel *The Peripheral* when I had one of those nerdy, late-night realisations: cyberpunk has become the retro-future, a vision of tomorrow that feels like the past. Even Gibson himself, who coined the term "cyberspace", has stopped writing cyberpunk, a subgenre devoted to corporate dystopias centred on virtual reality and sentient AI. *The Peripheral* is a far cry from his 1980s novel *Neuromancer*, in which hackers "jack into" a virtual metropolis. *The Peripheral* conjures a very different world, where kleptocrats from the future have figured out how to send data back in time and are using it to manipulate people.

Its high-tech setting is nothing like a glittering cyberpunk megacity; instead, it is a country town full of disabled military veterans and gamers desperately trying to earn a buck online. Our characters are dealing with poverty and climate change and broken democracy. Technology didn't bring them together in cyberspace – instead, it tore them apart in real life. Gibson uses this heightened representation of the present to suggest that we should change our expectations about what the future will bring.

He isn't the only one letting go of the cyberpunk retro-future. The gigantic financial fart emitted by Facebook's transformation into Meta, the virtual reality company, speaks volumes about what people believe the "next big thing" will be. With the threat of a global recession looming, people aren't fantasising about working in a virtual, Meta-branded office. They just want a job with benefits and paid leave – or where 50 per cent of the staff isn't laid off in a week.

As the cyberpunk vision explodes, its philosophical underpinnings are also melting down. Silicon Valley's investment in VR and AI was pushed in part by a belief in the "singularity". Described by sci-fi author Vernor Vinge in the 1990s, this is a hypothetical event in which technological advancement accelerates so fast that humanity is transformed. As Vinge once told me, experiencing the singularity would be like seeing new peaks rise on the horizon. Self-aware computers would be evolving so fast they could remould the planet in the time it took to eat breakfast.

In the early 21st century, Vinge's idea spawned a field of semi-mystical philosophies devoted to the emergence of AI and our imminent demise. Some, like Eliezer Yudkowsky's Machine Intelligence Research Institute (MIRI; formerly the Singularity Institute), want to stop future AI from destroying us. Others, like the Leverage Institute (now known as Leverage Research), have hazier motives, like wanting to "debug" minds so people can think rationally about scientific progress. These groups, mostly located in the San Francisco Bay Area, prophesied a cyberspace-like future where our minds would be projected into a techno-world created by AI. Their "thought leaders" were embraced by Silicon Valley luminaries like billionaire Peter Thiel and AI programmer Ray Kurzweil (author of *The Singularity is Near*).

> **"William Gibson's representation of the present suggests we should change our expectations about the future"**

But over the past couple of years, singulatarian organisations have been losing their mindshare. A number of former staffers at Leverage have said it was "similar to an abusive relationship". A researcher at MIRI wrote of how the group made her so paranoid about AI that she had what she calls a "psychotic break" leading to her hospitalisation. In response, MIRI pointed to the use of psychedelics in "subgroups". The singulatarian community is looking less like smart visionaries and more like cult survivors.

The Peripheral replaces the singularity with another vision of how technology will transform civilisation. Instead of a high-tech turning point driven by powerful AIs, it imagines the "Jackpot", a series of horrific, human-caused events that have wrecked the planet. The population has plummeted, while the rich "klept" class of the future uses quantum tunnelling to send data back to the present. There, they set up corporations that can funnel money to various groups. Some do it to change the future, but most are just amusing themselves, treating people like avatars in a game. The scenario is a literalisation of Gibson's famous comment that "the future is here, it's just unevenly distributed".

The point is that AI will not usher in a new phase of existence. Instead it will make a small number of pseudo-monarchs very rich, and the rest of us will become their playthings, struggling to survive in a post-Jackpot world where resources are diminishing. Cyberpunk imagined virtual worlds based on 20th-century technocracy. But *The Peripheral*'s vision suggests our prospects look quite different. Now, it feels like we are tottering towards a scenario where the most vulnerable will be abused by leaders who believe they are from the future. ▮

CONFLICT APPEAL

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An MSF medic treats a patient onboard the medical train. Photograph © Andrii Ovod/MSF

CHRISTOPHER STOKES IS COORDINATING MSF'S MEDICAL WORK IN UKRAINE

23 October 2022

"On 10 October I had just left the train station in Dnipro, eastern Ukraine, when the car started shaking. A second later, we heard the blast from the first missile. By the time we reached the office, we'd felt four more shockwaves from strikes. Since then, there have been regular waves of bomb attacks targeting infrastructure and civilian areas.

We're now gearing up for the possibility that the electricity will go off across Ukraine as a result of these ongoing attacks. That will have drastic knock-on effects on hospitals, healthcare and people's lives. People are heading into winter with the risk there will be no electricity, heating or hot water.

We're doing our best to prepare. We're helping a number of hospitals near the frontline get ready. We're running mobile clinics in areas previously under Russian occupation where people have had no access to the medicines they need for months. MSF operates a specially designed medical train that evacuates patients from near the frontlines of the fighting to safer areas and we're looking at ways to keep that running, even if the electricity fails. It's been kitted out with an intensive care unit and inpatient carriages. To date, we've evacuated 1,851 patients in 60 trips, most of them suffering from blast injuries and shrapnel wounds.

Last weekend we carried one family on the train who needed to be evacuated from the war zone. They had returned to their home in Nikopol on 5 October after having fled the war months earlier. On 6 October, their house was hit by a shell. One of the daughters was badly injured and ultimately had to have both legs amputated. She was only six years old.

The Ukrainians are doing the bulk of the medical work in this war. Our role is about filling the gaps. With these latest attacks, people's medical needs are growing, and it's vital we are here."

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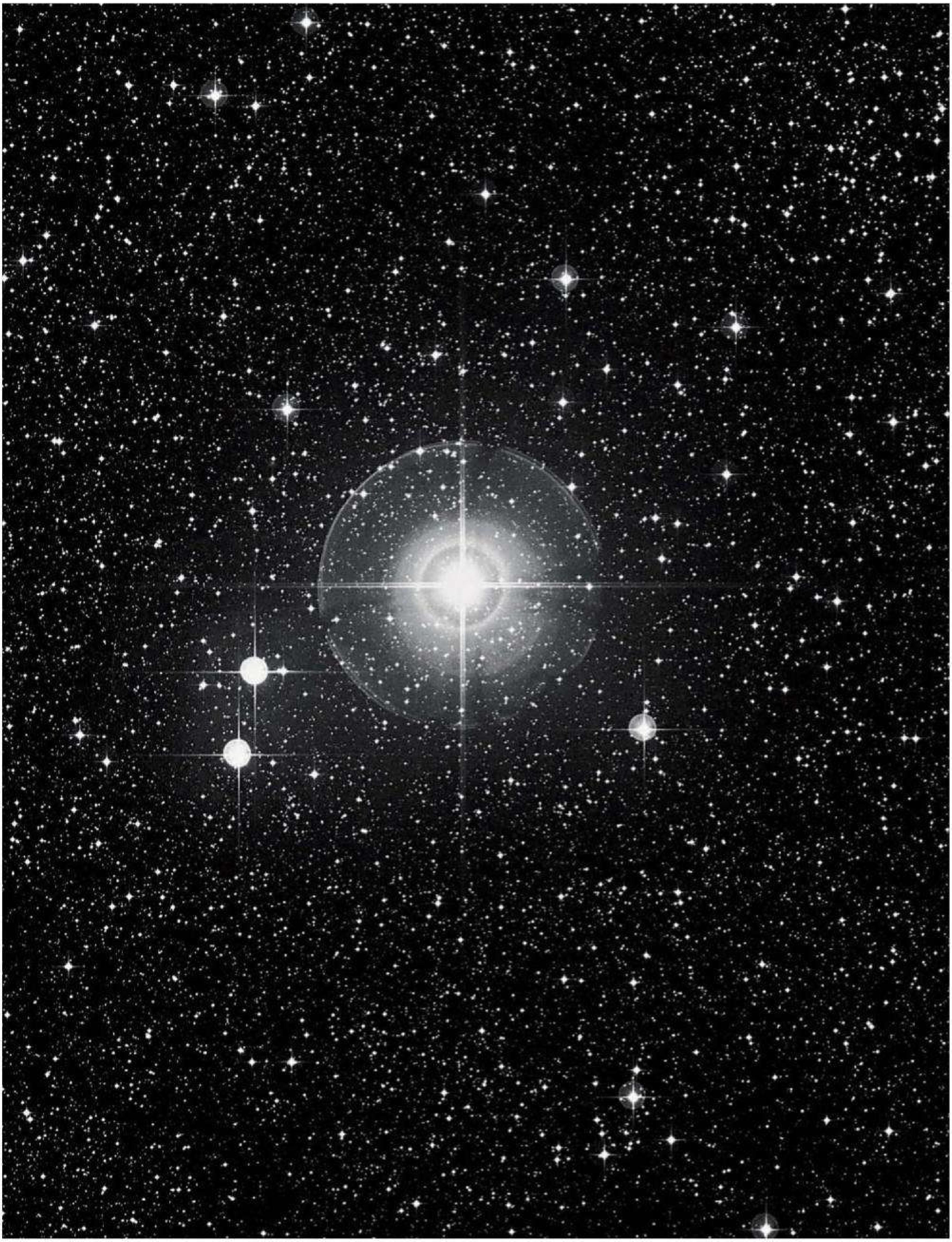

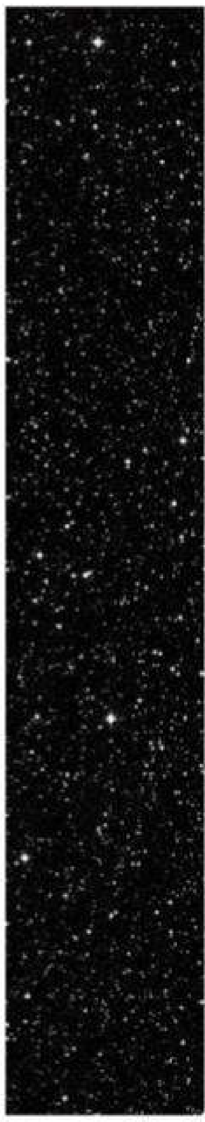

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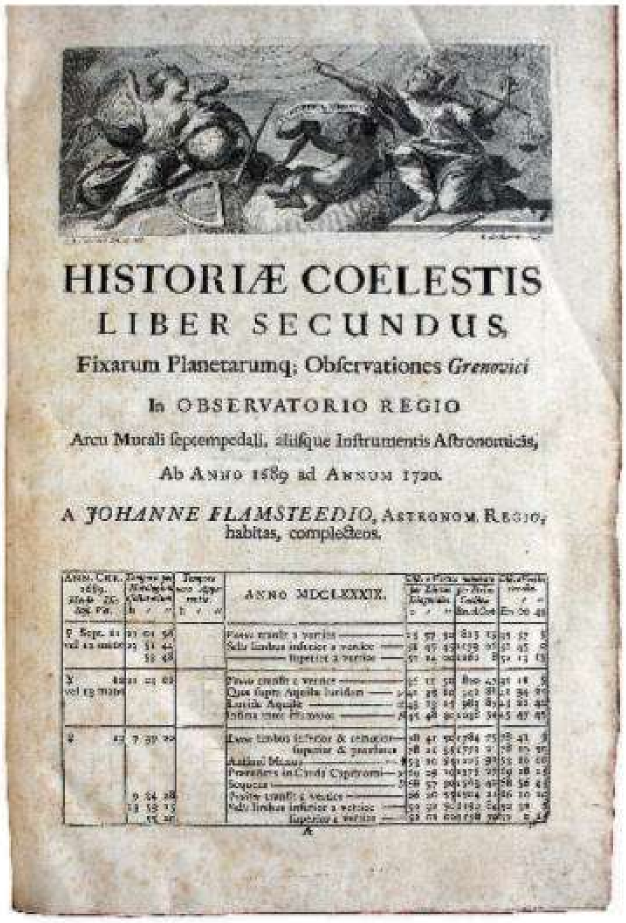
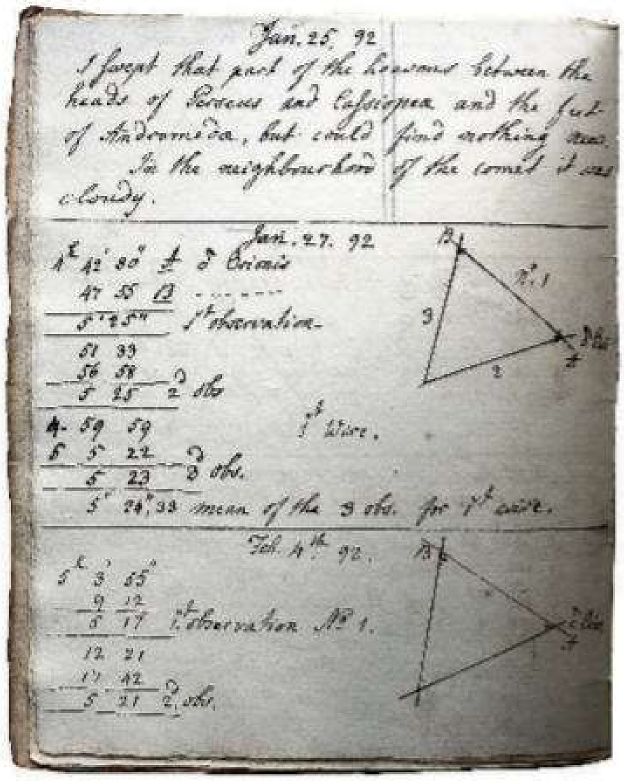
Forgotten stars

Photographer Lynda Laird



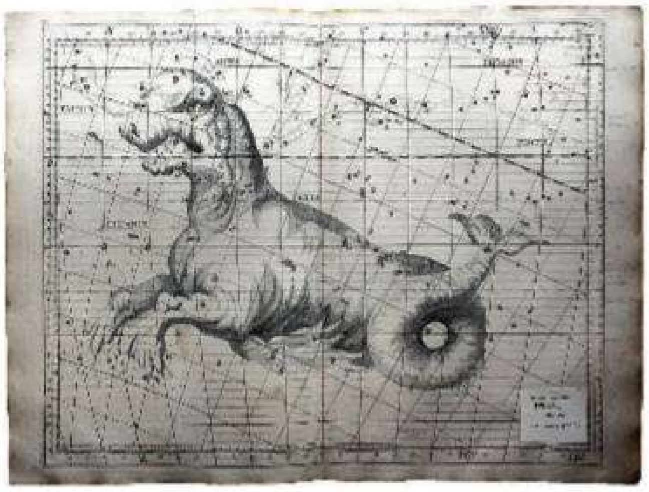
HISTORIÆ COELESTIS
LIBER SECUNDUS,
Fixarum Planetarumq; Obſervationes *Grenovici*
In OBSERVATORIO REGIO
Arcu Murali ſeptempedali, aliiſque Inſtrumentis Aſtronomicis,
Ab Anno 1689 ad Annum 1720.
A *JOHANNE FLAMSTEEDIO*, Astronom. Regio,
habitas, complectens.



Jan. 25. 92
I swept that part of the heavens between the heads of Perseus and Cassiopea and the feet of Andromeda, but could find nothing new.
In the neighbourhood of the comet it was cloudy.

Jan. 27. 92
1h 42' 30" ± δ Orionis
47 55 13
5' 25" 1st observation
51 33
56 58
5 25 2d obs
4 59 59 1st Wire.
5 5 22
5 23 3d obs.
5' 24",33 mean of the 3 obs. for 1st wire.

Feb. 4th. 92.
5h 3' 55"
9 12
5 17 1st observation No 1.
12 21
17 42
5 21 2d obs.



THE ROYAL ASTRONOMICAL SOCIETY

THESE striking images of stars are a modern representation of work done in the 18th century by Caroline Herschel. Herschel, who is considered to be the first professional female astronomer, discovered eight comets and 14 nebulae. She also revised the catalogue of stars by England's first Astronomer Royal, John Flamsteed, presenting the Royal Society in 1798 with a catalogue of 560 stars that had been omitted.

In 2020, photographic artist Lynda Laird began a residency at the Royal Astronomical Society, reacting to Herschel's life and work. Laird created 560 photographic glass plates of the missing stars Herschel spotted, featuring them in her new audio-visual installation *An Imperfect Account of a Comet*. Laird says she intends her work to represent "all the women whose groundbreaking knowledge and wisdom has been overlooked, undervalued, and ignored throughout history".

Pictured are some of these plates, showing stars located in the constellations of Gemini (left), Monoceros (middle, top) and Cygnus (middle, bottom). Shown top right is volume two of Flamsteed's *Historiae Coelestis*, which Herschel used in her studies and also corrected; middle right is a page of her observational journal; and lower right is her copy of a map of the constellation Cetus, from Flamsteed's *Atlas Coelestis*.

An Imperfect Account of a Comet runs at Jodrell Bank in the UK from 18 November 2022 until 16 April 2023. ▮

Tim Boddy

Editor's pick

Hopes and fears for the global climate

Leader, 29 October

From Kimon Roussopoulos, Cambridge, UK

You say that the biggest obstacle to progress at COP27 is the energy crisis that came after Russia's invasion of Ukraine. The invasion was an evil act, but it has had the consequence of increasing fossil fuel costs, raising incentives for energy efficiency and saving, insulation and so on.

Hopefully, one day, the war will end and some of the reduction in fossil fuel usage will have stuck.

From Larry Stoter, The North, Monmouthshire, UK

That thousands of politicians, business leaders, advisers and hangers-on are jetting to COP27 in Egypt tells us all we need to know about the chance of significant action on climate change. COP27 could have made an immediate contribution to cutting carbon emissions by moving online.

On calls to rename James Webb Space Telescope

29 October, p 28

From Simon Robinson, London, UK

Chanda Prescod-Weinstein objects to naming the James Webb Space Telescope after James Webb because of his political views and, in particular, his failure to oppose discrimination against LGBTQ+ people in the US in the 1950s and 1960s – discrimination that was utterly appalling.

She goes on to suggest renaming the telescope in honour of Harriet Tubman. Tubman was undoubtedly a hero who saved many lives. But that has nothing to do with science. To name a scientific instrument after someone who made no contribution to science, purely because it fits in with today's political concerns, is to devalue science and scientists.

Let us remember past scientists, technicians and engineers for their contributions to their fields, without seeking to judge them because they lived at a time when social attitudes were different.

Are all living things linked with each other?

15 October, p 44

From Graham Hagens, Hamilton, Ontario, Canada

One could imagine a social aspect to the nature of reality explored in Michael Brooks's fascinating article on whether objects exist. To a great extent, human awareness of self relies on reflections of one another, in addition to the less cognitive reality around us. Perhaps all living creatures are inextricably entangled.

Arguably, the more one flirts with the hubris of solipsism, the greater the danger of approaching a black hole of derangement.

On the growing concern of UK blackouts this winter

15 October, p 9

From Sam Edge, Ringwood, Hampshire, UK

The prospect of power blackouts and possible calls for consumers to cut use at peak times reminds me of what a waste of money the rollout of first and second-generation smart meters in the UK has been. If we had waited until these devices could communicate intelligently with high-current appliances, such as storage heaters, the problem would be solved.

From Rachel Mckeown, Cambridge, UK

The potential need to radically change household and business energy consumption reminded me, a neuroscience PhD student, of the "three Rs" of replacement, reduction and refinement. We are trained to apply these in the lab, but it is time they became cornerstones of all our lives, not just the lives of researchers. Replace inefficient appliances, reduce laundry temperatures and refine the use of central heating.

Geothermal energy may not win over everybody

29 October, p 16

From David Hurburgh, Opossum Bay, Tasmania, Australia

The potential for geothermal energy in the UK gives cause for optimism that this carbon-free power can be exploited. To date, the only parts of the world with electricity generated geothermally are those with active hydrothermal vents associated with volcanism, such as Iceland and New Zealand.

When Australia looked at the idea of geothermal energy using "hot rocks" outside volcanic areas, it was found this would require fracking of water-bearing aquifers to increase the transmission of heat. And the source of the warmth below ground? Radioactive decay of uranium and its daughter isotopes. Prepare for the inevitable meltdown by eco-warriors.

Fusion doesn't come free of resource issues

Leader, 22 October

From Eric Kvaalen, Les Essarts-le-Roi, France

You say that if we could tame nuclear fusion we would have a "virtually unlimited supply of clean energy". While it is true that deuterium, one of the inputs, is virtually unlimited, we would also need lithium. One estimate of how long lithium reserves would last if fusion supplied a large portion of our energy is 990 years – and that is if the metal weren't used for batteries. Theoretically, it could be extracted from seawater, but this would entail processing 50 cubic kilometres of seawater per year.

How to stop the armed robots in their tracks

15 October, p 11

From Geoff Harding, Sydney, Australia

Amid concern over the arming of robots, I suggest that, while laser weapons shouldn't be used to deliberately blind or disable human adversaries in war, it would seem reasonable to use such weapons on robots. For a more low-cost method, a paintball pellet fired at visual sensors could do the job.

Remember, space budgets are a drop in the ocean

Letters, 1 October

From Manek Dubash, Lewes, East Sussex, UK

The debate about whether we should spend more on reducing poverty and improving the environment – both laudable objectives – rather than sending people into space ignores the behemoth in the room: global defence spending of more than $2 trillion in 2022. NASA's budget is some $24 billion, around 1 per cent of that total. Those calling for a reduction in space exploration are barking up the wrong tree.

Ungrowable seeds from crops are nothing new

Letters, 29 October

From Julian Little, Great Dunmow, Essex, UK

Graeme Hurry worries about genetic modification being used to develop crop varieties that produce "ungrowable" seed, so that more has to be bought each year. However, this has been the case with F1 hybrid varieties – which make up the vast majority of our vegetable, maize, sugar beet and oilseed crops – since the 1930s.

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The hunt for consciousness

Despite our best efforts, we are still struggling to account for consciousness. Does a new hypothesis take us further, wonders **Philip Ball**

Book

Sentience: The invention of consciousness

Nicholas Humphrey

Oxford University Press

JONATHAN KNOWLES/GETTY IMAGES

THERE is a shelf in my brain – and in my study too – where I store theories of consciousness, and this is where psychologist Nicholas Humphrey's new book, *Sentience,* will reside. Each of these theories and hypotheses can seem compelling in the moment, especially given the confidence with which they tend to be presented. They are usually unlike each other; often, they are diametrically opposed.

For example, in *Sentience*, Humphrey invokes children born with hydranencephaly, a condition where the brain's cerebral hemispheres are absent, replaced by sacs filled with cerebrospinal fluid. These hemispheres control key areas like muscle function, speech, thought, emotion and learning. Neuroscientist Mark Solms also invokes such children in his book *The Hidden Spring*. For him, the children's responses to their environment imply that consciousness is lodged in the brain stem. For Humphrey, it shows the opposite. And so on.

I don't mean to be dismissive. *Sentience* is full of provocative ideas, as well as lively anecdotes from decades of pondering these issues. Humphrey's thesis offers a great deal to think about. But it doesn't persuade any more than the others.

Even the terminology is contentious. Humphrey considers sentience to be a "higher" form of consciousness than what he calls cognitive consciousness, in which the mind is merely aware of stimuli that influence behaviour; in sentient "phenomenal consciousness", these perceptions are accompanied by subjective feelings philosophers call qualia, perhaps the biggest battleground of the philosophy of mind. But some others working on these problems consider sentience as a primitive form of consciousness, a mere buzz of awareness.

> "There is no strong argument why consciousness could not be primarily a neutral adaptation"

Humphrey's distinction is illustrated by the phenomenon of blindsight, in which people with a damaged visual cortex who don't report "seeing" objects still respond to them because the retina has registered them. In fact, we respond to all manner of bodily sensations without representing them phenomenally: we are cognitively, but not phenomenally, conscious of them.

Once, argues Humphrey, all consciousness might have been only cognitive: senses informed actions, but their signals weren't presented to the self along with corresponding qualia. He implies that most non-human animals, at least up to the complexity of frogs, might have minds like this. In truth, we have little idea if that is the case.

Humphrey denies sentience even to octopuses, writing that the likelihood of their being sentient and having a phenomenal self is "negligible". He adds later: "If you were in the place of a sentient dog, you would mind about being treated well by humans; if you were in the place of an insentient octopus, you wouldn't." On what basis does he argue this? In part, he thinks only sentient animals "play" – but it isn't clear what counts as play, and it has been posited that octopuses and even insects engage in it. Humphrey's arguments are less than compelling, so the assumption is morally contentious.

> **Why did evolution invest in giving humans so much feeling about their world?**

Wherever it begins, phenomenal consciousness changes everything. "It's an invention so sublime," Humphrey writes, "that, if it were to cease to exist, it would indeed diminish the whole of creation." Having it, we have a duty to preserve it.

If this is so, why did evolution invest in giving us so much feeling about our world? Humphrey insists it must be adaptive, and may be advantageous to creatures who engage in complex sociality.

I am not so sure. What's more, there is no consensus on whether our consciousness is adaptive, and, however important it seems to us, no strong argument why it could not be primarily a neutral adaptation. Humphrey doesn't consider this, though it has been proposed that much of the complexity in higher animals arose this way.

So I fear Humphrey provides no more compelling an explanation of sentience or consciousness, or how they arose, than those other volumes on my shelf.

But his book earns its place among them, and is a valiant reminder of how much there still is to understand. ▮

Philip Ball is a writer based in London. His latest book is *The Book of Minds*

Life at its most basic

An ambitious new book is a love letter to the cell and a reminder of what we still have to learn, finds **Jason Arunn Murugesu**

Book

The Song of the Cell
Siddhartha Mukherjee
Bodley Head

ON 25 July 1978, Louise Joy Brown was born at Oldham General Hospital in the UK. The first child to be born following IVF, she was called a miracle baby by some, a test-tube baby by others, and a representation of the "degeneration of Western morals" by at least one.

A hundred years earlier, Walther Flemming, a German scientist, coined the term chromatin, meaning coloured substance, while he was looking at stained human cells dividing under a microscope. The thickening and division of chromosomes, structures that are formed from chromatin, must be key for successful cell division, Flemming concluded.

The joy of Siddartha Mukherjee's new book, *The Song of the Cell: An exploration of medicine and the new human*, is that these two episodes happen within just a few pages of each other.

Mukherjee describes how Robert Edwards, one of the pioneers of IVF, struck an ecstatic note as he described finally figuring out a way to keep human egg cells primed for fertilisation in a petri dish.

"Excitement beyond belief," Edwards wrote. "The chromosomes were just beginning their march through the centre of the egg."

An apparently straightforward insight about chromosomes in one century has now become life-changing for hundreds of thousands of people in the next. This trick of linking seemingly small observations about the cell to their profound implications years later is used by Mukherjee to electrifying effect throughout his book.

There are other highlights. Take the causes of common diseases, such as diabetes. Mukherjee analyses them forensically, making clear the difficulty and time it took to understand them.

He is also excellent when charting the history of our understanding of the immune system. On the invention of vaccination, he gives credit to the Indian and Chinese physicians who practised a basic form of inoculation centuries before Edward Jenner realised that having had cowpox could protect a person against smallpox.

The book is ambitious in its scope, ranging widely from the realisation, in the 1600s, that all living things were made from cells to the dramatic promises of gene therapies today.

However, this is both its strength and its key weakness. Detailing a hundred years of failure, discovery and more failure in a few pages makes for an exciting read, but it left me wishing that Mukherjee, who won a Pulitzer prize for his earlier book *The Emperor of All Maladies: A biography of cancer*, would take a bit more time to detail each of the topics in the book.

For example, he describes the neuron as perhaps the "most subtle and the most magnificent" cell of them all, but spends only a brief chapter on the topic. The impact of covid-19 on human cells also receives just a single chapter, though this is easier to accept since we are only now starting to understand the virus.

The book is at its strongest when discussing cancer, which makes sense considering Mukherjee's day job as an oncologist. For anyone new to the biology of cancer, his writing is a revelation. He details the complexities of treating cancer and explains clearly why the disease has been – and continues to be – so difficult to treat. By describing in moving detail his experiences with people with cancer, he shows us the consequences of the gaps in our knowledge.

It has been more than 350 years since Robert Hooke coined the term cell. In the time since, we have devised all sorts of ways to manipulate them – even editing the genes of embryos. *The Song of the Cell* is both a love letter to its subject and a passionate reminder of how much we still have to learn about this most basic unit of life. ▮

In less than 50 years, the IVF process has gone from pioneering to commonplace

NEVODKA/ALAMY

Don't miss

Watch

Black Panther: Wakanda Forever finds Queen Ramonda (Angela Bassett, pictured) and her kingdom of Wakanda fighting to survive after the death of King T'Challa (the late Chadwick Boseman). In cinemas 11 November.

Read

"You Are Not Expected to Understand This" collects the human stories behind the algorithms that govern and shape our everyday lives. Editor Torie Bosch asks whether computer code can ever keep up with human values. Out on 15 November.

Visit

The Science and Philosophy of Self Consciousness sees Anil Seth (pictured) debate Louise Antony, Maja Spener and Philip Goff at the London School of Economics on 16 November at 6.30pm GMT.

TOP: MARVEL STUDIOS; LOWER: CARLOS FIGUEROA ROJAS (CC BY-SA 4.0)

Journey to a better world?

A new blockbuster exhibition isn't so much about science fiction as it is about involving you in a compelling story. Have fun, says **Simon Ings**

Exhibition

Science Fiction: Voyage to the edge of imagination
Science Museum, London
Closes 4 May 2023

ISIDORA BOJOVIC/SCIENCE MUSEUM GROUP

Visitors to the Science Fiction exhibition must board an alien craft

LONDON'S Science Museum has come up with a solution to the age-old problem of how to keep visitors from bunching up while they navigate an exhibition.

In an awkward corner of Science Fiction: Voyage to the edge of imagination, ALANN (short for Algorithmic Artificial Neural Network) announces that all the air is about to leave the room – sorry, "deck". To avoid the hard vacuum of outer space, it asks that you please move along.

Little fillips of jeopardy enliven this whistle-stop tour of science, technology and imagination. It isn't so much an exhibition about science fiction itself – London had that in 2017 with the Barbican's superb Into the Unknown – as it is an experience that creates its own sci-fi.

The gallery is arranged as a story, which begins once a Pan Galactic Starlines shuttle drops us aboard an alien craft, the Azimuth. The Azimuth's friendly, if bemused, resident AI is orbiting Earth and pondering the curious nature of human progress, which puts imagination and storytelling ahead of practical action.

It seems to ALANN – who jumps from screen to screen, keeping us company throughout – that using stories to imagine the future is a weirdly double-edged way of going about things. Humans could just as easily be steering towards nightmares as happy outcomes. What will their future hold?

ALANN bottles that question in the end, of course: our destiny turns out to be "uncomputable". Oh, how I wish for a show that had punters running screaming for the exits! Isn't that what sci-fi is for?

> **"At the end of it, we have bent space-time, communicated with aliens and become post-human"**

Assembled on a low budget, and featuring not a whole lot of film props, costumes and replicas, which never looked that good at the best of times, this "voyage to the edge of imagination" stands or falls by its wits. Next to a cheery video about communicating with humpback whales as a rehearsal for alien "first contact", some bright spark has placed a life-size xenomorph from the film *Alien*. Iron Man's helmet is close by, too, promoting our eventual "cyborgisation", the melding of metal and flesh to better handle our technological future – but so, mind you, is Darth Vader's helmet.

The sheer lack of stuff here is disconcerting, yet by the end of the exhibition, we have explored space, bent space-time, communicated with aliens and become post-human, so clearly the experience is well-crafted. Imagine an excellent nest constructed from three sticks.

Sci-fi's imaginative and philosophical richness is better revealed in the fabulous accompanying book, by project curator Glyn Morgan. It features interviews with influential writers and commentators, like Charlie Jane Anders and Chen Qiufan.

This being the Science Museum, it is hardly surprising that the exhibition's final spaces are given over to pondering the practical utility of sci-fi. For this, futurologist Brian David Johnson is on screen to explain how fiction can be used to prototype ideas before they arrive in the real world. Sci-fi writers already have a word for this: they call it plagiarism.

But whether you give credence to Johnson's belief that sci-fi is there to make the world a better place is more of a glass-half-full, glass-half-empty sort of question.

In a cabinet nearby are some copies of Marvel Comics's *Captain Planet and the Planeteers*. In the 1990s, we are told, Captain Planet "empowered a new generation to be environmentally aware". As someone who was there, I promise you that he jolly well didn't.

But as I turned the next corner, the sneer still on my lips, I saw as fine an example of transformative imagination-in-action as you could wish for. Tilly Lockey, who has been wearing bionic arms since she was 8 years old, had been invited along to the press launch, and was skipping about, taking photos of her friend. In the gloom, I couldn't quite see which arms she was wearing – the ones based on the *Deus Ex* video game series or the ones designed by the team behind the film *Alita: Battle Angel*.

In any case, that was me told. Tilly's bionic arms are as much the result of sci-fi-inspired design as technical innovation: an example of how sci-fi can be applied to make life better. ▮

Simon Ings is a writer based in London

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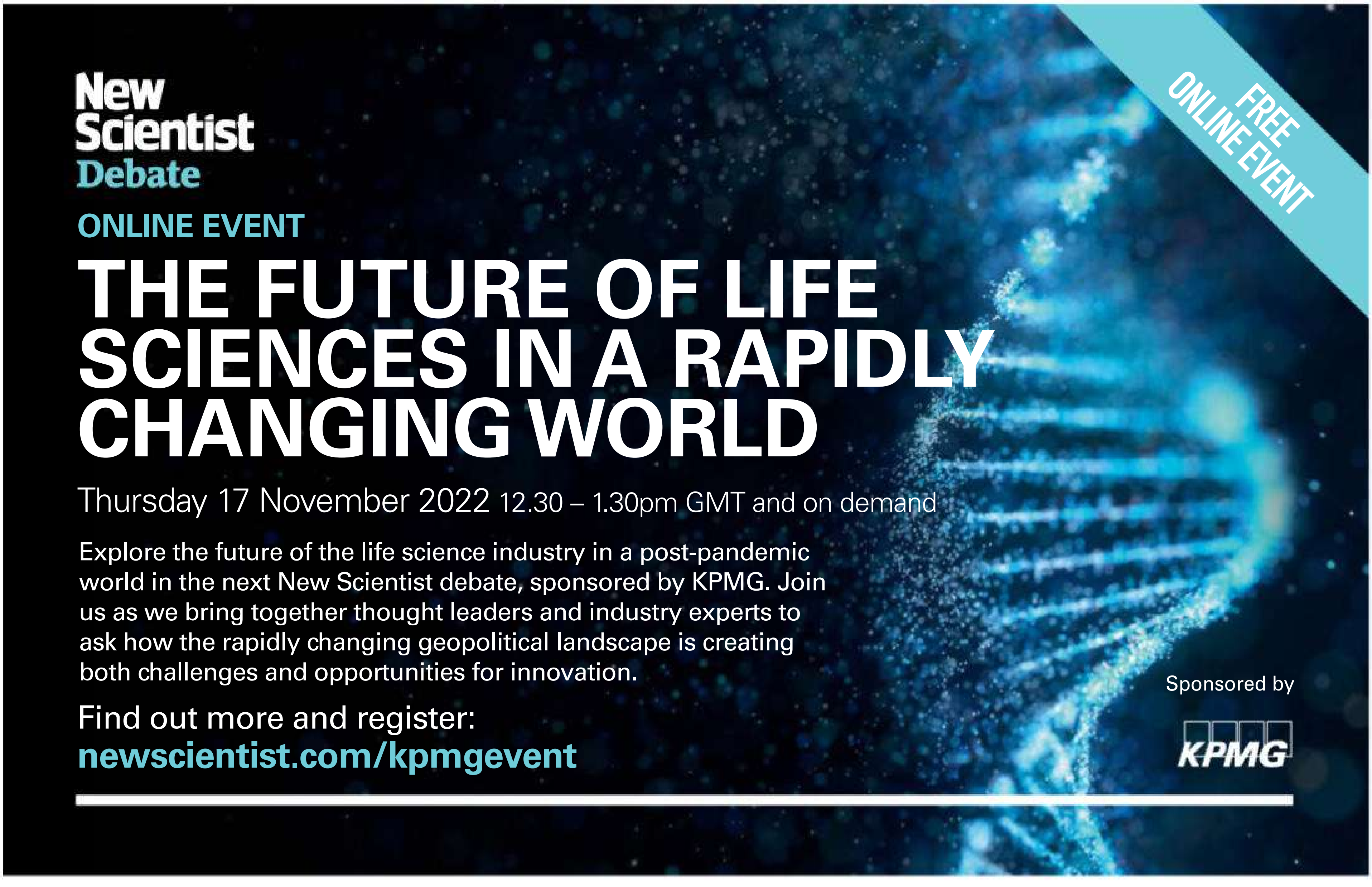

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Alien skies

Astronomers can now peer into exoplanet atmospheres like never before, transforming the search for life beyond Earth. So what's the plan, asks **Stuart Clark**

WHEN the first observations from the James Webb Space Telescope (JWST) were made public in July 2022, the images of deep space were so breathtakingly beautiful that it was easy to overlook the dowdy-looking graph released alongside them. The world was agog at the majestic panoramas of clouds of gas and dust from which stars are born, and the shining spiral shapes of ludicrously distant galaxies. Yet for many astronomers, the graph, a simple curving line, was just as jaw-dropping. It heralded a new era in the search for alien life.

Showing the unambiguous detection of water vapour in the atmosphere of an exoplanet called WASP 96b, it was the first proof that this powerful telescope would be able to deliver what many had doubted, namely, precise details of the contents of atmospheres on worlds beyond our solar system. Just as the beauty of some of those deep-field images captured the imaginations of the public, the quality of this unprecedented graph electrified astronomers. Suddenly, it was clear we really can peer into alien skies like never before. Finally, we have a fighting chance of spotting the subtle signals that would prove life exists elsewhere – not that it will be easy.

Now, astronomers are plotting their next moves. Having whittled down the most promising planets, they are lining up observing time with JWST to probe their atmospheres, thinking again about what signs of life we should be looking for – and sizing up the prospects of success. "I feel like we're at the beginning of a really exciting journey," says Laura Kreidberg at the Max Planck Institute for Astronomy in Heidelberg, Germany.

Exoplanetary atmospheres contain all manner of clues about what the planet is made from. We study them with a technique called spectroscopy, which takes advantage of the fact that different atoms and molecules absorb different wavelengths of light (see "Cloud spotting", page 38).

The first success in probing alien skies came in 2002, when David Charbonneau, then at the California Institute of Technology, and his colleagues used the Hubble Space Telescope to watch a gas giant world called HD 209458b, nicknamed Osiris, cross the face of its parent star. As it did so, Hubble detected a small dimming of the star's light at the wavelength absorbed by sodium. The effect disappeared when the planet moved off the face of the star, meaning it must have been caused by sodium in Osiris's atmosphere.

Alien weather

From then on, astronomers gradually began to dip their toes into analysing exoplanet atmospheres. The initial targets had to be worlds that block an appreciable amount of starlight. These turned out to be the largest and nearest examples of "hot Jupiters", gas giant planets that sit inexplicably close to their parent star, completing a single orbit in just a couple of Earth days.

For years, astronomers caught glimpses of elements and molecules in the atmospheres of such exoplanets. Then, in 2017, we saw the real power of spectroscopy when it comes to characterising worlds beyond our solar system.

Thomas Mikal-Evans, then at the University of Exeter, UK, and his colleagues used Hubble and the infrared Spitzer Space Telescope to study WASP-121b. Watching this hot Jupiter, 850 light years from Earth and about 1.81 times larger than Jupiter, revealed the first water vapour seen in an exoplanet atmosphere. But they didn't stop there. After studying WASP-121b for a full orbit, about 31 hours, the team glimpsed something extraordinary. Temperatures on the planet's dayside, facing the star, were so high that they ripped water molecules apart, producing hydrogen, oxygen and hydroxyl. The heating drove tremendous winds on the planet, sweeping these molecules round to the nightside, where temperatures dropped sufficiently for them to recombine into water. It was the first evidence for weather in another solar system.

"We were actually able to measure this happening by tracking how the spectral feature of water changed from the dayside to the nightside hemisphere," says Mikal-Evans, now at the Max Planck Institute for Astronomy.

The temperature difference was so great, the team speculated, that simple minerals like corundum, a form of aluminium oxide, could also be vaporising on the hot side and condensing into clouds on the cool side. Corundum forms the basis of rubies and sapphires, meaning the clouds on WASP-121b could be made of ruby and sapphire dust.

Until recently, however, the technology enabling spectral analysis of alien skies has had its limits. "With all of the power of Hubble and Spitzer and ground-based telescopes, we've only learned a little bit about what to expect for these atmospheres," says Kreidberg. "We have seen just the very tip of the iceberg."

With the help of JWST, we are now diving below the surface. That is because JWST outstrips its predecessors on three main counts. First is its position in space. Far from Earth's orbit, this telescope can keep its targets precisely aligned on its sensors, reinforcing the detection of even faint signals. Second, JWST has a 6.5-metre-diameter mirror, a big step ›

GRAHAM CARTER

PROMISING PLANETS

When it comes to habitable worlds we can search for atmospheres, the options are limited. These are today's best candidates.

LHS 1140b
Discovered in 2017 by the Whipple Observatory, Mt. Hopkins, Arizona, this is a dense super-Earth 6.48 times more massive than Earth, and with 1.64 times the radius. Depending on its atmosphere, its surface temperature could be very Earth-like.

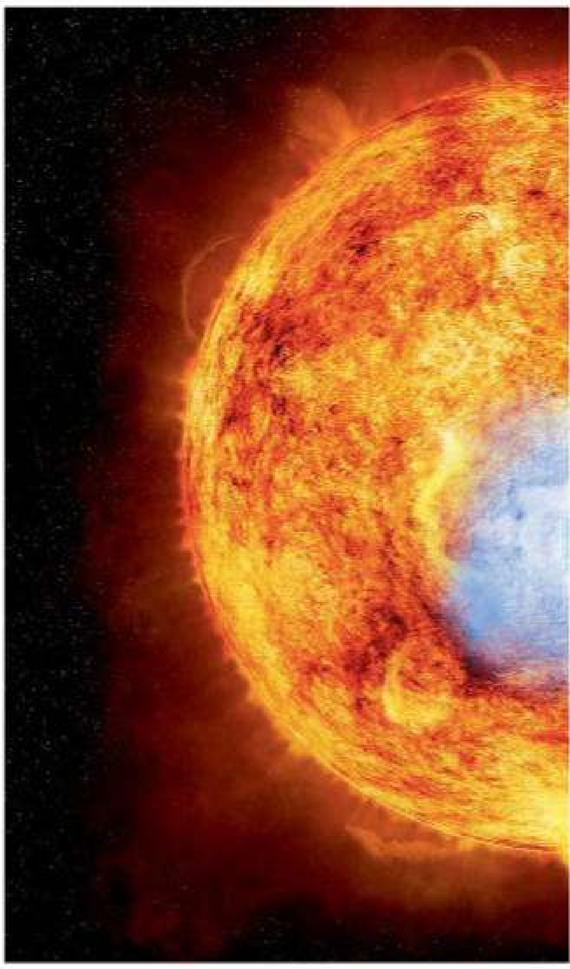
TRAPPIST-1d
The star TRAPPIST-1 hit the headlines in 2016 and 2017 with the announcement of seven planets in orbit around it. Of those, at least three might be in the ultra cool dwarf star's habitable zone. TRAPPIST-1d has 0.78 times the radius and 0.3 times the mass of Earth.

TRAPPIST-1e
Very similar in its physical characteristics to Earth, TRAPPIST-1e has 0.91 times the radius and 0.77 times the mass of our world. If the planet possesses a relatively thin atmosphere like Earth, its surface temperature could be similar to ours.

TRAPPIST-1f
With a mass of around 0.68 times that of Earth, and a very similar radius, TRAPPIST-1f is just inside the outer edge of its star's habitable zone. It would require a modest greenhouse effect to raise its surface temperature to Earth-like levels.

K2-18b
Discovered in 2015 by NASA's Kepler space telescope, K2-18b has water vapour in its atmosphere and is in the habitable zone of its parent star. But with 8 times the mass and 2.6 times the radius of Earth it is either a rocky "super-Earth" or a gaseous "mini-Neptune".

LP 791-18c
Another super-Earth / mini-Neptune, LP 791-18c was discovered in 2019 by NASA's Transiting Exoplanet Survey Satellite (TESS) mission. It has 2.3 times the radius and 5.95 times the mass of Earth and sits near the inner edge of its star's habitable zone.



up from Hubble's 2.4-metre-diameter mirror, which allows JWST to collect a lot more light, revealing fainter details. Perhaps its biggest advantage, though, is that it works across the infrared spectrum. That is a boon because molecules love to interact with light at these wavelengths. "The infrared is the richest spectral region if you want to see absorption by molecules," says Drake Deming at the University of Maryland. And JWST's mirror is more than 7.5 times larger in diameter than previous infrared telescopes, like Spitzer.

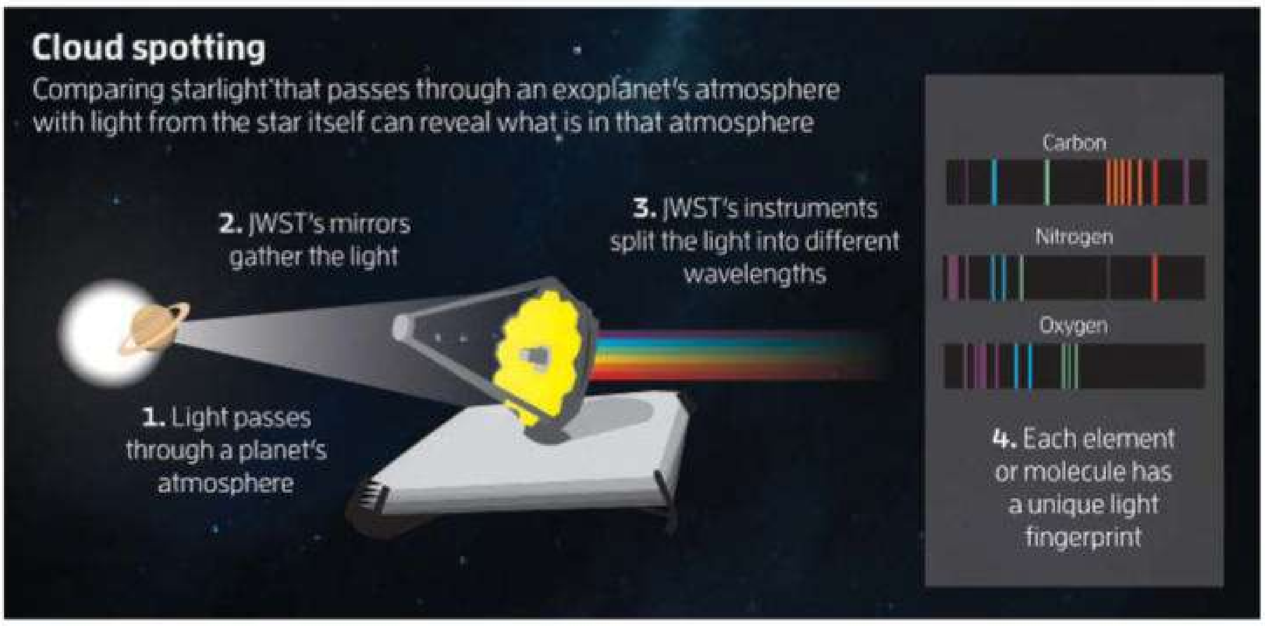
What all of this means is that, for the first time, astronomers have a real shot at seeing the details of the atmosphere of a rocky exoplanet, which is generally considered the best bet for finding potential signs of life.

What we are looking for are smaller rocky planets with atmospheres, like Earth, that happen to orbit within the habitable zone around a star, where temperatures would allow liquid water to exist at the planet's surface. The trouble is that smaller worlds, with less gravitational heft, can only retain relatively tenuous atmospheres. (For example, Earth's atmosphere contributes less than 1 per cent to its radius.) So if we want to detect their atmospheres with JWST, these rocky worlds also have to be relatively near.

Those criteria alone hugely narrow the number of viable targets. "For rocky planets that are in the habitable zone and accessible to JWST, we're talking definitely less than 10," says Kreidberg (see "Promising planets", left).

Even then there are complications. Each of the target planets orbits its own small red dwarf star. These stars are cooler than the sun, so their habitable zones are much closer in than that of the sun, which could make it difficult for the planet to retain an atmosphere. A case in point is the poster child of target systems – TRAPPIST-1, an ultra-cool red dwarf star around 40 light years from Earth with seven known rocky planets. This star's surface temperature is less than half that of the sun's, which means its habitable zone is extremely close to the star. So although three or four of the TRAPPIST planets sit in the habitable zone, there is no guarantee that they have atmospheres. "It's possible that they're all bare rocks," says Kreidberg.

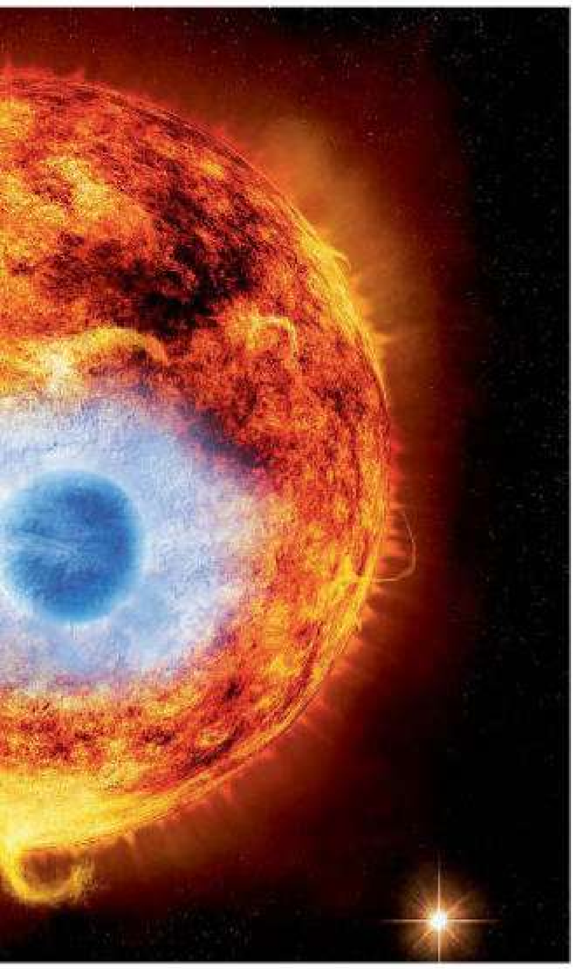
Although this particular red dwarf is today



Cloud spotting

Comparing starlight that passes through an exoplanet's atmosphere with light from the star itself can reveal what is in that atmosphere

2. JWST's mirrors gather the light
3. JWST's instruments split the light into different wavelengths
Carbon
Nitrogen
Oxygen
1. Light passes through a planet's atmosphere
4. Each element or molecule has a unique light fingerprint



NASA/CXC/M.WEISS

An artist's impression of a hot Jupiter passing its star

> **"It would really be delightful if we saw a biosignature we didn't expect"**

cooler than the sun, the situation was reversed during its formation. A star forms when a pocket of interstellar gas contracts under the force of its own gravity. In the process, it releases a torrent of high energy radiation. Smaller stars have weaker gravity and so take longer to contract, meaning that they are releasing this flood of energy for longer than their larger cousins. This could blast away any atmospheres from nearby planets that are forming.

With all that in mind, Kreidberg will use JWST to observe the TRAPPIST-1 planets as they move in front of and behind their star. The idea is to determine the difference between their day and night temperatures, which will in turn tell her whether each has an atmosphere or not. Atmospheres tend to efficiently distribute heat around a planet, so the day and night temperatures tend to be similar. A bare rock with no atmosphere will heat up on the dayside and then radiate that energy directly into space on the nightside, giving a different temperature profile.

Once we know there is an atmosphere, it will be time to try to get a spectrum and look for the signatures of life. Based on what we know on Earth, the best things to look for are the spectral fingerprints of oxygen and methane. All living things respire; they take in one gas or substance, extract energy from it and then expel a waste gas. In the case of animals, oxygen is the input and carbon dioxide is the output. For plants, it is vice versa. In animals, metabolising food also produces other waste gases, like methane. All of this builds up in a planet's atmosphere, knocking it out of chemical equilibrium – and producing a detectable signature.

Indeed, the oxygen that we now rely on for life is an excellent example. Earth's earliest microbes obtained energy via photosynthesis and, like today's plants, produced oxygen as a waste product. Other microbes evolved to metabolise the oxygen. Seeing oxygen and methane together in an exoplanet atmosphere would be the closest thing to a slam dunk we can currently imagine. These two gases are biologically produced on Earth and otherwise wouldn't co-exist in the air. Without constant replenishment by living things, they would chemically react and vanish from the atmosphere.

Signs of life

TRAPPIST-1e is the planet that gives the best chance of such a detection. Perfect conditions would raise that chance, but seem unlikely in reality. The list of them is long. "If we're really, really lucky and the planet has exactly the atmospheric composition we are expecting, JWST performs so perfectly that we can stack up data again and again and again and again to beat down the noise, the atmosphere doesn't have clouds and there's no contamination in the spectrum from the host star, which we already know is not true," says Kreidberg. "All of those things would have to happen before we could have a prayer of identifying the biosignature."

Put like that, it sounds next to impossible, but such an assessment is based on what we know of life on Earth. "The one thing which would really be delightful is if we saw a biosignature somewhere we didn't expect," says Deming, "Everyone's thinking of rocky planets, like the Earth with solid surfaces and thin atmospheres, but maybe not."

For example, he would love to see something from an exoplanet that resembles Neptune. Roughly five times the diameter of Earth, and predominantly composed of icy materials, a number of these Neptune-class planets have been discovered around other stars. Intriguingly, some have migrated close enough to their respective stars that they could be covered in global oceans – on the face of it an excellent venue for life. And with larger atmospheres to start with, such hot Neptunes should make JWST's job easier.

When it comes to biosignatures, a new generation of researchers is starting to increasingly think outside the box. Justin Wang at the University of Colorado, Boulder, proposes looking for a set of molecules called polyhydroxyalkanoates (PHAs). These are a family of polyesters made exclusively by microbes. As such, they can be thought of as bioplastics, and wherever they occur, they seem to have some remarkable properties.

"I found many types of microorganisms that use PHA," says Wang, "and I found that in many of the [microbes known as] extremophiles, the bioplastics are the explanation for how they can survive in those environments." This is music to the ears of an astrobiologist because extremophiles, as the name suggests, live in harsh environments that most other life on Earth would find toxic. So maybe bioplastics are exactly the kind of molecules that we should be looking for.

At present, Wang thinks that such searches are more easily conducted in places like Mars, where robots can scoop up samples of dirt and process it. He can't easily think of a situation in which PHAs would build up to create a detectable signal in a planet's atmosphere. Nevertheless, the idea raises the possibility that perhaps we have thought too narrowly so far about the biosignatures we are looking for – or the places to seek them.

As researchers work their way through nearby exoplanets with JWST, we may be in for a very big surprise. The next time NASA and the European Space Agency make a big deal out of a wavy line, it could be because we have answered that big old question: are we alone in the universe? ▮

Stuart Clark is a consultant for *New Scientist*. His latest book is *Beneath the Night* (Faber)

When I grow up

Becoming an adult represents a dramatic turning point in everybody's life. But when does it actually happen? **Moya Sarner** goes in search of what really makes us a grown-up

BOONE RODRIGUEZ/GALLERY STOCK

AS A woman in my mid-30s, I look very much like a grown-up. I have a career, a home and a husband; I have deliberated over and purchased a dishwasher, a washing machine and a fridge. Judge me by my white goods, and I tick all the boxes.

But when, one Saturday, I opened my kitchen bin to find the lid heaving with maggots, I felt totally helpless. So I called my mum. It was a crushing realisation: I may look like a grown-up, but I didn't feel like one. It got me thinking, if a house and a spouse don't make an adult, what does?

If you go by traditional milestones, people in the West seem to be growing up later than ever. The age of the average first-time home buyer in the UK has risen by seven years over the past six decades. In the US, the average age of a first marriage increased by about eight years over the same period. And the proportion of women in Australia having their first child when over the age of 30 more than doubled between 1991 and 2019.

Yet according to UK law, the answer is straightforward: an adult is anyone who is 18 or older. This age determines so much, from whether you can vote and how you can access the National Health Service (NHS) mental health services, to whether you can get a drink in a pub. It is hard to overstate the impact this definition can have on the lives of young people, which is why I wondered whether it needed a rethink. At what age do we really become adults?

While writing my book *When I Grow Up*, I interviewed various people whose stories highlight why it is so important to better understand our transition to adulthood. Boru, for instance, told me his mental health had plummeted in his mid-teens: he refused to go to school, wouldn't eat, became addicted to drugs and attempted suicide. At 17, he was admitted as an inpatient to the adolescent unit of a psychiatric hospital and stayed there for several months, with later re-admissions for brief periods. He had access to a psychotherapist, took part in creative group activities and began to feel he was recovering. Then he turned 18.

While there are some mental health services in England that treat young people up to the age of 25, this isn't the norm, and it wasn't the case for Boru. He couldn't continue to see the same therapists he had come to know and trust, couldn't return to the same hospital he felt safe in. Boru was diagnosed with drug-induced psychosis and admitted to a psychiatric hospital again – this time in the adult department. "I was being told: 'You are an adult now, and we're going to treat you as such,'" he says. He was terrified: "I was shitting myself. Everyone's older than you, and you're the little kid."

Adult architecture

Many neuroscientists, such as Sarah-Jayne Blakemore at the University of Cambridge, push back at such a strict definition of adulthood. "The idea that the brain suddenly becomes mature [at 18] isn't true," she says. "The brain is not a uniform piece of tissue,

it is made up of different regions, which each develop at different rates, and different people's brains mature at different ages."

Blakemore and her colleagues found that certain areas of the brain can still be developing well past the age of 18, through to our late 20s. These include the prefrontal cortex, which is key to decision-making, understanding other people and risk-taking; the temporal cortex, which is involved in language and memory; and in the parietal cortex, involved in movement and navigation.

Another aspect of brain development, called pruning, also continues past the age of 18. We are born with many more connections, or synapses, between neurons in the brain than we need. At around 8 months old, a process of elimination begins, whereby useful synapses are strengthened and others are removed. This streamlining of our neural architecture is fundamental to our cognitive functions, and studies show that it only begins to taper in our mid-to-late-20s, sometimes even into our 30s.

We might also consider the development of white matter in the brain to be important to when we become adults. White matter is made up of long fibres called axons, which are covered in a fatty substance called myelin. This increases in volume as we grow up and is associated with faster transmission of electrical signals – and therefore information – around the brain. Studies show that this volume continues to increase throughout our 20s, 30s and possibly 40s.

So your brain is maturing well past 18. And, one could argue, it never really stops. No matter how old you are, every time you have a new experience, your brain develops: this phenomenon is known as neuroplasticity. "There is no age limit to plasticity," says Blakemore. "We are constantly evolving and learning and adapting and changing."

"If a house and a spouse don't make an adult, what does?"

So if studying the brain can't provide us with an answer, where else can we look?

Jeffrey Arnett at Clark University in Worcester, Massachusetts, has been researching when young people begin to feel like adults. He made his mark in developmental psychology 20 years ago by defining this process as a new life stage called "emerging adulthood".

Arnett has conducted dozens of studies, interviewing hundreds of people across the US, asking them whether they felt like adults and what that meant for them. He says he took great care to include people with a range of educational qualifications from varied socioeconomic backgrounds. Arnett found that most people began to feel like an adult somewhere between the ages of 18 and 29: early in this period, he explains, very few people feel like adults, but by the end of it,

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almost everybody he asked replied yes, they did. They would then usually mention responsibility, which links what he calls "the big three", the core elements that constitute adulthood. According to the vast majority of his interviewees, these were the capability to take care of themselves, being able to make their own decisions and having financial independence.

Over the three decades that Arnett has been asking people in the US this question, the answer hasn't changed, he says. It isn't a global answer, however. In 2014, Arnett's colleague Juan Zhong, now at Springfield College, Massachusetts, travelled to China to interview 119 female factory workers in Guangdong. The participants, aged 18 to 29, completed a questionnaire of markers for adulthood, then 15 were interviewed on their understanding of this transition. The responses were subtly but significantly different from those in the US. The "big three" criteria of adulthood were orientated more around taking responsibility for others, rather than for oneself. They included learning to care for parents, settling into a long-term career and feeling capable of caring for children. Despite the global disparity in the detail, by Arnett and Zhong's definition, most people around the world feel like adults by age 29.

But when it comes to measures of adulthood, the big three criteria from these studies paint only a partial picture. You could argue that being an adult is also about how we tolerate and make sense of our emotions.

This is the kind of growing up that I see a lot in my work as a psychodynamic psychotherapist in the NHS. As young infants,

When do animals grow up?

In the animal kingdom, it has long been assumed that it is the capacity to reproduce that differentiates adults from their young. Yet in 2020, Barbara Natterson-Horowitz, a cardiologist and evolutionary biologist at Harvard University, overturned that assumption. She and her colleague Kathryn Bowers, an animal behaviourist and author, spent five years studying the transition to adulthood in wild animals around the world, from grey wolves and humpback whales to African elephants. They concluded in their book *Wildhood* that the ability to reproduce isn't synonymous with adulthood.

For many species in the wild, puberty – the physiological process of becoming reproductively mature – is just the beginning. "These young animals lack adult skills in many areas. They may lack courtship skills because they haven't learnt mating dances, or they may not have social skills to acquire status," says Natterson-Horowitz.

She points out that it was widely believed that newly adult penguins, having shed their soft brown down and now sporting their black and white feather tuxedos, would dive into the water and head off to create families of their own. But Natterson-Horowitz and her colleagues discovered that if there isn't enough food or if the penguins' hunting skills aren't sufficiently developed, those in a number of species return to their parents, who continue to feed them – what researchers call "extended parental care". "They've left home, but come back because they can't yet make it on their own," she says.

Over five years of conducting large systematic reviews of adolescence across species and fieldwork observing animal adolescents in natural settings and sanctuaries, Natterson-Horowitz and Bowers arrived at a new definition of adulthood based not on an animal's capacity to reproduce, but on the mastery of four key competencies: staying safe, navigating social hierarchies, sexual communication and leaving the nest to care for itself. "Safety. Status. Sex. Self-reliance," says Natterson-Horowitz. Master all four and you have an adult animal. Could the same be said for humans? (See main story.)

Newly mature penguins sometimes return home if they can't make it on their own

VINCENT MUNIER

“As we transition into adults, we develop more and more sophisticated means to deal with our feelings”

ANTONIO GARCIA RECENA/GETTY IMAGES

DEMAERRE/GETTY IMAGES

Moving house, having a baby, fixing a broken boiler – what makes you feel like a grown-up?

we defecate or scream or lash out to deal with our emotions. As we transition into becoming adults, we develop more and more sophisticated means to digest feelings. This may not be a clear-cut measure of adulthood, but it has meaning as a measure of the growth of an internal capacity to process the world in a more mature way.

Such “emotional intelligence” appears around age 4 and develops at different rates in different people. There is no consensus on when your emotional intelligence stops developing, if it ever does. However, a study in China did show emotional intelligence was directly related to the age at which a person experiences high affective well-being, which is defined by a balance of positive and negative emotions – a characteristic some might associate with settling into adult life.

Baby brain

When considering the transition to adulthood we should also consider reproduction, a common signifier for many people of becoming a “proper” grown-up (see “When do animals grow up?”, left).

To find out whether reproduction makes its mark on the maturing brain, Elseline Hoekzema at Amsterdam University Medical Centre in the Netherlands scanned the brains of people who wanted to become pregnant before and after giving birth, then compared the results with those who didn’t become pregnant. The brain changes after pregnancy were so strong and consistent that a computer algorithm could detect all of the people who had been pregnant based only on their scans. “It was truly exceptional,” says Hoekzema.

The structural changes were most apparent in brain regions that play a role in theory of mind, which is the capacity to understand someone else’s psychological state, emotions and thoughts. “It’s an ability that plays an important role in parenting,” says Hoekzema. “It seems that these structural changes help prepare a woman’s brain to optimally respond to cues of her infant and help prepare her for her new role,” she says. Studies showed these changes persist for at least two years after giving birth.

There are strong indications that pregnancy entails a further maturation of the brain, or at least a further specialisation that benefits the next phase of life, says Hoekzema. You don’t have to grow up before you become a mother, it seems; pregnancy itself causes changes that help you to mature.

An alternative way to think about when we become adults is to consider when our brain starts to decline. Perhaps this might give some clues as to upper limits? Not so fast. Jon Simons at the University of Cambridge studies middle age. In neurological terms, he says, this period, between 40 and 60, was historically thought of as a time where nothing much happens. “People neglected it for the more sexy and exciting parts of life,” he says.

Now, though, studies have shown that parts of our brain begin to decline before we hit our 40s, even as others are still maturing. Brain scans have shown this deterioration most clearly in the frontal lobes, which we use to make plans and solve problems. Other studies of executive functions, including things like working memory – the ability to hold information in mind – and planning, show that these skills can start to decline as early as the third decade of life.

Thankfully, this midlife decline in cognitive skills will be barely noticeable in everyday life, says Heather Ferguson at the University of Kent in the UK. But it does underlie the onset of significant difficulties that people experience in older age, she says. “Understanding that these changes begin as early as our 30s is important for us to begin looking for precursors and consequences in the midlife period.”

This counter-intuitive revelation – that our brains can grow and deteriorate in tandem throughout our 30s and onwards – sums up the complexities involved in pinning down the onset of adulthood. Even if we consider all of the valid definitions of adulthood, it seems to occur somewhere between puberty and our late 40s.

For some, adulthood may arrive even later. Pog was 90 years old when I spoke to her for my book. I asked her if she was a grown-up. She laughed and said: “I’m quite shocked really. I truly do not consider that I have grown up.” I asked her if she feels she will manage to finish growing up before the end of her life and she replied, thoughtfully: “I hope not.”

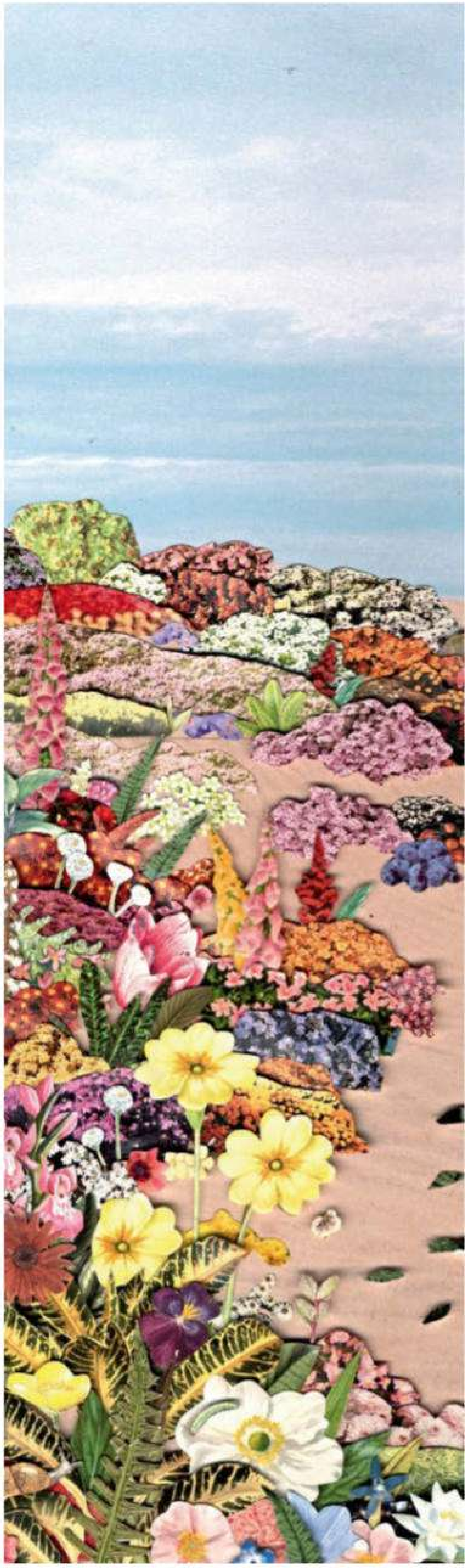
For people like Boru, subject to an arbitrary definition of adulthood, a more nuanced and scientific view of when we become a grown-up would be life-changing. For me, Pog’s answer has the most meaning for when we finish growing up: the lucky ones never do. ▮

Need a listening ear? UK Samaritans: 116123 (samaritans.org). Visit bit.ly/SuicideHelplines for hotlines and websites for other countries

Moya Sarner is the author of *When I Grow Up: Conversations with adults in search of adulthood*

Flower power

As floral plants took over the world, they usurped the bloom-free gymnosperms that once dominated the planet. How did they win the battle, asks **Penny Sarchet**


BEN GILES

ARGUABLY the world's weirdest plant, *Welwitschia mirabilis* is a tangled mass of shredded, fraying leaves in the Namib desert. For a thousand years, perhaps more, it grows just two long leaves, which creep continuously outwards for many metres, becoming torn and ragged. The plant is a lone survivor; fossils suggest its family dates back at least 112 million years to the middle of the Cretaceous, but all its close relatives are gone.

This evolutionary orphan is a gymnosperm – plants that produce seeds, but not true flowers or fruit. The most familiar today are conifers, a group that includes the longest living organisms on Earth, the bristlecone pines, and the coastal redwood, the world's tallest trees. But gymnosperms also comprise gnetales (like *W. mirabilis*), the palm-like cycads and ginkgo, also known as the maidenhair tree. When dinosaurs roamed Earth, they walked among the gymnosperms, which dominated the land. But just as the dinosaur era ended with the Cretaceous, so too did the heyday of the gymnosperms. Today, there are only around 1000 species, mostly conifers. They cling on in a world conquered by a quarter of a million angiosperm species – the flowering plants.

What went wrong? Until recently, the tale has been that gymnosperms didn't stand a chance against these beautiful newcomers. Flowers enabled angiosperms to use insects for pollination, boosting their reproductive success and spurring them on to global dominance. But the latest research reveals new twists in this ancient whodunnit. By better understanding why gymnosperms lost out, we may get some clues about their future, too.

Flowers have long been implicated in the gymnosperms' demise due to timing: when the angiosperms began evolving into many new forms, the gymnosperms went into decline. But we now know that flowers were around for perhaps tens of millions of years before this explosive diversification and march to dominance, which was already taking place in some environments by around 100 million years ago. This is thanks to new techniques for finding and studying mesofossils – tiny fossils that are visible to the naked eye, but need microscopic analysis to reveal their details.

Pioneered by Else Marie Friis at Aarhus University in Denmark, these methods involve carefully sorting, sieving, cleaning and rinsing small fragments of organic material and studying them using electron microscopy and a means of seeing internal details called tomographic imaging. This approach has provided previously unimaginable insights into the relationships and biology of ancient flowering plants, says Peter Crane, president of the Oak Spring Garden Foundation in Virginia.

Crane (favourite gymnosperm: ginkgo) has worked with Friis to analyse many of the earliest known flower fossils. "The abundance of Cretaceous angiosperm flowers that could be obtained using these techniques was a genuine surprise," he says. In a deposit north of Lisbon, Portugal, they have found some of the earliest, unequivocal flower fossils, dating to around 125 million years ago, and they already showed some diversity. The flowers were all quite simple and resembled living angiosperm relatives like magnolias and water lilies, but variations in structure – such as the number of petals – suggest that these fossils may represent as many as 30 different species of early angiosperm.

Some researchers believe they may even have found Jurassic flower fossils, possibly

dating back 164 million years, while attempts to use genetic analyses and other types of modelling to infer the origin of flowering plants have produced even earlier dates. These very early dates are regarded with some scepticism by other botanists, however. But based on the research from Crane, Friis and other researchers, we can conclusively say that flowers themselves arose some time before the angiosperms swept to dominance, suggesting this evolutionary invention wasn't enough on its own to put paid to the gymnosperms. So what else might explain their downfall?

Ancient relationships

One of the great advantages of flowers is that they enable angiosperms to attract animal pollinators to streamline their efforts to move pollen around and reproduce. Perhaps the breakthrough moment for angiosperms wasn't the emergence of their flowers, but when their flowers adapted to become particularly good at manipulating insects.

Once again, new fossils are offering some surprises. They contradict the idea the angiosperms invented insect pollination in the Cretaceous, and show – quite remarkably – that insects have been pollinating gymnosperms since the preceding period, the Jurassic, before many experts think flowers even existed.

Today, the gymnosperms that many of us are most familiar with – the conifers and ginkgo – are wind pollinated. But hundreds of cycads and gnetales, including *W. mirabilis*, are pollinated by insects. Until recently, however, it was unclear whether this reflected an ancient relationship between gymnosperms and pollinators, or a more recent occurrence.

"Twenty years ago, we were dealing with just a few isolated glimpses," says Michael Engel at the University of Kansas (favourite gymnosperm: cycads). The lack of insect fossils from the Cretaceous, particularly the early Cretaceous and the Jurassic, left researchers with little to go on. But since then, "it's like the Earth has been vomiting up material", says Engel, thanks to advances in finding fossil deposits from this time, particularly amber. As a result, the Jurassic and Cretaceous have gone from being lamentably fossil-poor to one of the best-known windows of time, he says.

This abundance has enabled Engel and others to finally catch ancient gymnosperm pollinators red-handed. In 2018, he and his colleagues published a study of a 99-million-year-old, mid-Cretaceous beetle preserved in amber with cycad pollen. Like its living relatives, the beetle had various specialised

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The ginkgo has no close surviving relatives

body parts that could carry and store pollen, including a cavity in its mandible. "It has specialisations for transporting pollen, and the pollen is not uniformly distributed in the amber – there is a concentration of it around these mouthparts," says Engel, whose study estimates that this beetle-cycad relationship could have emerged in the Jurassic. And this wasn't a unique plant-insect relationship either – a variety of insects, including thrips and flies, have also been implicated in pollinating a range of different types of gymnosperm in the Jurassic and early-to-mid-Cretaceous.

Simply harnessing insects for reproduction can't, therefore, be the secret to flowering plants' success. But the timing of the rapid boom in flowering plant evolution might nevertheless provide a clue, since it coincides with the emergence of some particularly good pollinators. The fossil record for bees is still poor, but it is thought that, some time in the mid-Cretaceous, some carnivorous wasps became vegetarian, started eating pollen and began diversifying into thousands of bee species. "I would say bees are certainly a very important player," says Engel.

The emergence of bees also coincided with an explosion in the diversity of a group of moths and butterflies, known as the ditrysia. "They're incredible pollinators, and they're tightly associated with that same time period when bees are taking off," says Engel. Today, we have some 20,000 species of bees, but more than 150,000 butterflies and moths, almost all of which belong to the ditrysia group.

Thanks to the colours, odours and nectar of their flowers, angiosperms were able to form tight relationships with these newer, highly effective pollinators. "All of this is far more effective than anything that gymnosperms had [developed]," says Engel. "So now you've got a group that's really predominantly taking advantage of animal vectors."

Case closed, you might think: the bees' and butterflies' preferences for flowers drove the angiosperms' rise and diversification and – as a consequence – the fall of the gymnosperms. But a few obvious counter-examples prevent such a neat conclusion. "Think of the grass family," says Patrick Herendeen at the Chicago Botanic Garden (favourite gymnosperm: ginkgo). "Grasses are one of the most diverse families of flowering plants and they're wind pollinated. So there's something else going on there that has allowed the grasses to diversify to the great extent that they have."

ROGER WHITEWAY/GETTY IMAGES

"It's like the Earth has been vomiting up insect fossils"

Above: A 99-million-year-old beetle carrying cycad pollen. Below: a *Welwitschia mirabilis*

Herendeen agrees that animal pollination is "certainly a big factor" in the angiosperms' success, but suggests other aspects of the angiosperm life cycle – such as the speed of fertilisation and seed formation that take place after pollination – could have also fuelled the diversification of flowering plants.

"The time that it takes to go from flowering to production of mature viable seeds is very short in most angiosperms," he says. "The gymnosperm group, they have quite a slow reproductive cycle. Pollination to seed maturation takes an incredibly long time, and then even when the seeds fall from the plant, they're not mature."

The evolutionary ramifications of this became clear in 2017, in a study by Amanda De La Torre at Northern Arizona University and her colleagues, which compared tens of thousands of points across the genomes of gymnosperms and angiosperms. They found that, just as some gymnosperms today look like living fossils, with the ginkgo, dawn

LOWER: MICHAEL SCHWAB/GETTY IMAGES; UPPER: CAI ET AL. CURRENT BIOLOGY 2018

INAYAJO/GETTY IMAGES

Monkey puzzle trees stand firm in the Chilean countryside

redwood and Wollemi pine all bearing a striking resemblance to ancient fossil remains, gymnosperms also appear remarkably unchanged at the molecular level. Many gymnosperm genes in today's plants look identical to their counterparts from millions of years ago, whereas angiosperm genes have accumulated mutations far more quickly.

Mutation is a double-edged sword – it provides new opportunities for evolutionary innovation, but it can also damage or harm an organism's basic functioning. "Angiosperms are changing way faster than gymnosperms. They may have a lot of deleterious mutations, but they also may have a lot of advantageous mutations," says De La Torre (favourite gymnosperm: Douglas fir). This may have enabled angiosperms to colonise geographical areas where gymnosperms weren't able to survive, she says.

Besides the effects of their slow reproduction, gymnosperms also have to contend with the sheer size of their genomes, which can be as much as seven times as large as a human genome. De La Torre's research suggests that this is also linked to gymnosperms' slow mutation rate. Indeed, across much of life on Earth, larger genomes have often been found to evolve more slowly.

The cell is the limit

To make matters worse, large genomes also directly affect the physiology of an organism's cells, setting a limit for the smallest size a cell can be. This can have a profound influence on a plant's anatomy and functioning, according to a recent study comparing the genome size and anatomy of 289 angiosperms and 53 gymnosperms.

The analysis revealed that angiosperms downsized their genomes in the Cretaceous period. Adam Roddy at Florida International University and his colleagues argue that this enabled them to have smaller cells, making it possible to pack their leaves with more veins and more stomatal pores for bringing in carbon dioxide for photosynthesis. "Smaller genomes allow for smaller cells and higher rates of photosynthesis, higher rates of growth," says Roddy (favourite gymnosperm: *Araucaria*, the monkey puzzle trees). "You can grow faster and outcompete your neighbours." The gymnosperms were unable to do the same.

This builds a picture of the angiosperms' formidable armoury – they could grow faster, evolve more quickly and use their innovative new flowers to reproduce very effectively via newly evolved bees, butterflies and moths that were undergoing their own rapid diversifications. It is easy to see how this could have led the angiosperms to suddenly evolve into a large number of new species.

Detailed modelling looking at the extinction rates of conifers suggests this diversification of angiosperms was the most important factor in the increased extinction rate of gymnosperms that began in the mid-Cretaceous. "Our work suggests that the diversity of angiosperms contributed to increase the extinction of conifers," says Fabien Condamine at the French National Centre for Scientific Research (favourite gymnosperm: *Araucaria*). This was particularly evident in tropical regions, where conifers once flourished until the angiosperms took over.

Condamine and his colleagues' work also suggests that global cooling around 34 million years ago may have played a secondary role. "We see a lot of extinction occurred at that time. It is possible that conifers were slow to adapt to this cooling trend," says Condamine.

Sadly, Condamine's work found that extinction rates for conifers have remained high ever since the mid-Cretaceous. According to researchers at Royal Botanic Gardens, Kew, in London, 40 per cent of gymnosperm species are deemed to be at high risk of extinction, making them one of the most threatened groups on Earth. We now know that slow-evolving gymnosperms don't appear to cope well with times of rapid climate change, which raises the alarm for how these plants will fare over the next century.

But we shouldn't write off gymnosperms as evolutionary losers. "I guess I've become a little defensive of the gymnosperms," says Roddy. Many are doing fine, he says, and they are in ecological settings in which their strategies for life seem to be working.

Today, the most threatened gymnosperm species tend to be those that have clung on in tropical regions. But many gymnosperms have now adapted to life in colder environments and conifers dominate many temperate and high-latitude forests in North America, Europe and Asia.

They may be slow to grow, reproduce and evolve, but gymnosperms have been on this planet for three times as long as their flowering plant relatives. It will be hundreds of millions of years before we know whether the flashier flowering plants are capable of such staying power. ▮

Penny Sarchet is news and digital director at *New Scientist*

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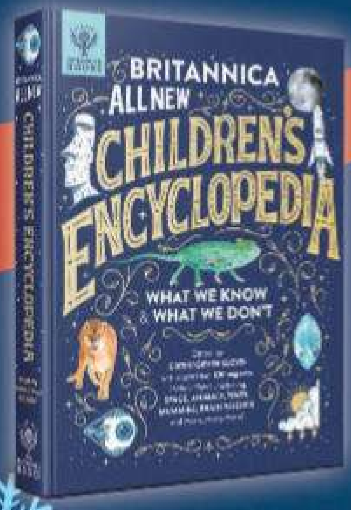

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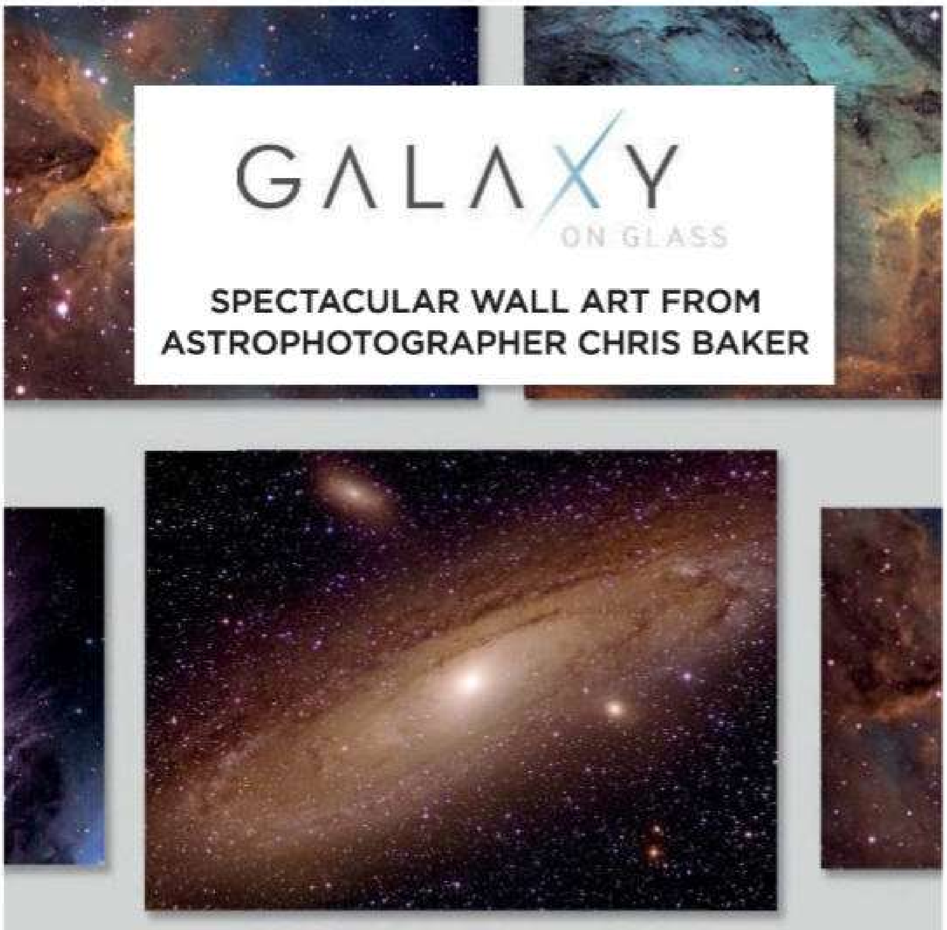

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***Almost* the last word**
What has been the most successful animal ever? p54

Tom Gauld for *New Scientist*
A cartoonist's take on the world p55

Feedback
Mathematicians and physicists tackle the Mona Lisa p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Science of gardening

Tulip fever

Growing great tulips means planting bulbs in late autumn, ensuring good drainage and seeing off squirrels, says **Clare Wilson**

Clare Wilson is a staff writer at *New Scientist* and writes about everything life-science related. Her favourite place is her allotment @ClareWilsonMed

What you need

Tulip bulbs
Pots
Bulb fibre or bulb compost
Chicken wire

AS IT is autumn in the UK, I have been planting bulbs of plants that will flower in spring. There is a huge variety to choose from, but my personal favourites are tulips.

While most varieties don't self-propagate – unlike other spring bulbs, such as daffodils – and they will often die after only one or two years, tulips are worth the effort of replanting every autumn for their elegant, cup-shaped blooms and intense, saturated hues.

During the 17th century, passion for tulips in the Netherlands led to the first known financial "bubble", when prices reached absurd levels before the market collapsed. Most prized were varieties with delicate streaks or feathery markings.

We now know that these patterns are caused by a viral infection. Different levels of tulip breaking virus in the cells of the petals lead to different amounts of pigment. The virus weakens the plant, though, and is passed down through the generations, so some of the varieties that were most prized during the "tulip mania" period, such as the exquisite white and red-streaked *Semper Augustus*, have died out.

Today's multicoloured tulips are a result of simple breeding, which means the patterns are more predictable – and they are in no danger of dying out.

GAP PHOTOS

Tulip breaking virus and some other viruses and fungi can still infect the plants, leading not only to unexpected streaky petals, but also to mottled leaves and stunted growth. If this happens, throw away the affected plants. Also, consider waiting until late autumn before planting the bulbs, as this reduces the risk of them contracting tulip fire, a fungal disease.

I grow my tulips in pots because it is easier than digging up my flower beds every autumn. All the food they need is in the bulb, so the plants only require compost with low nutrient levels. But they don't like to be too wet because they originally hail from the rocky soils of central Asia.

You can buy bags of well-draining bulb compost or fibre. Alternatively, you can make your own from coconut fibre or by adding grit to a multipurpose compost to improve its drainage, says Chris Taylor at the UK's Royal Horticultural Society (RHS). "If they get wet and cold, they could well rot," he says.

If you are going to try to get a second year out of the same bulbs, it is worth adding a tomato plant fertiliser, which will be high in potassium, while the plants are in leaf, so that they take the nutrients up into the bulb. The RHS website lists tulip varieties that are more likely to last several years.

To stop squirrels or other pests from tucking into your bulbs over the winter, cover your pots with chicken wire and firmly bend it over the rim. You can leave the pots in an out-of-the-way place until green shoots start poking up. Then, bring them back into full sun, remove the chicken wire and wait for the show. ▮

Science of gardening appears every four weeks

Next week

Citizen science

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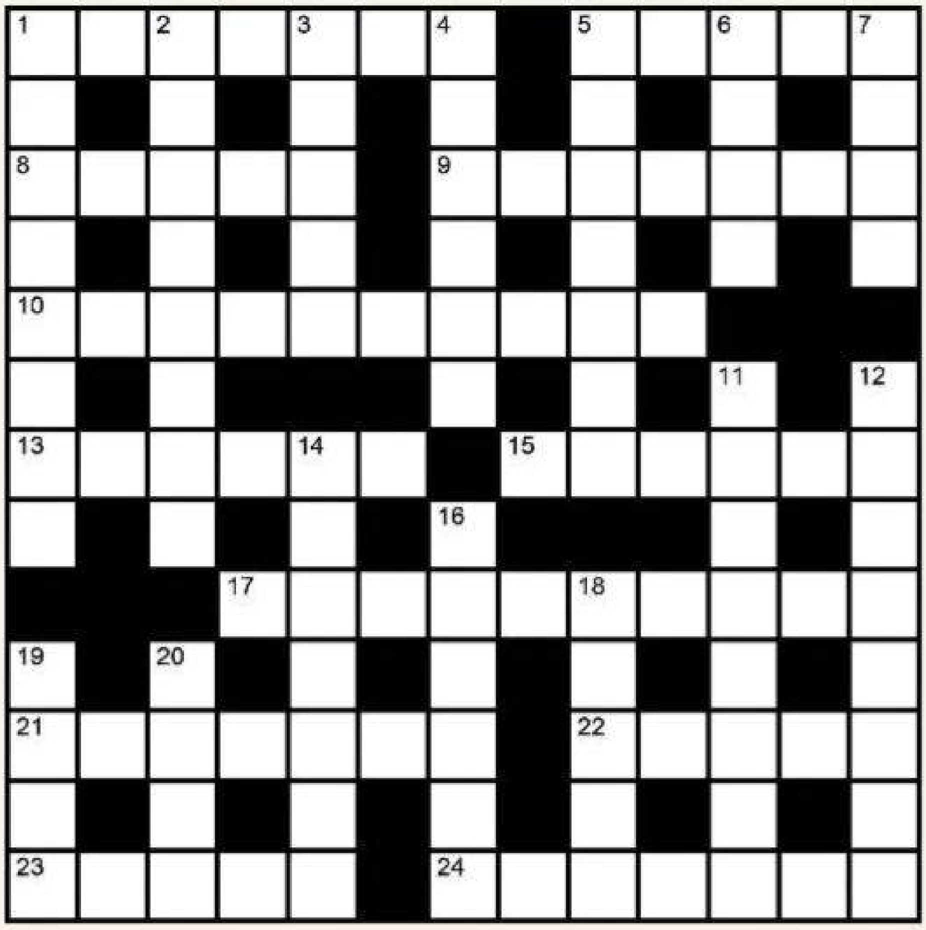
Cryptic crossword #96 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Iron bonded with type of fibre of the thigh (7)
5 Retro dance bar (5)
8 Bolts securing grand steps (5)
9 Fruit company added to count with minor adjustment (7)
10 Mathematician's goofy dares taking toll (10)
13 Countless millions returned milk products (6)
15 Crashing bore beyond street light (6)
17 Troublemakers contributed to most faded, overwritten document (10)
21 Piece of driftwood I'd turned into old-fashioned instrument for technophobe (7)
22 Guard second rowing team (5)
23 Our group have discussed fabric characteristic (5)
24 Rudest punk left pastry (7)

DOWN

1 Valuable rocks found in granges, and each one of these is finished by hand? (8)
2 Rue swimming after frenzied spa treatment (8)
3 Trios cooked Swiss potato dish (5)
4 Layer underlies semi-moistened caribou food (6)
5 Tangled elastic, most tuile-like (7)
6 Parisian goes with almost mint-condition windmill part (4)
7 Way to memorise nonsense by end of lecture (4)
11 Shabby coiffure adjusted (3-5)
12 At first, teens fall behind loading greenish-blue dryer (3,5)
14 Reportedly craving mineral found in bones (7)
16 Pen salesperson's lacking face muscles (6)
18 Question raised about small operation (5)
19 Built-in weapon initially causes concern for barristers (4)
20 Wide angle offers inspiration for a "Eureka!" (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #177

1 Who is the only person to have won a Nobel prize and an Ig Nobel prize?

2 The ability to detach a body part in response to a predator's threat is known as what?

3 Aqua regia is a mixture of hydrochloric acid and what else?

4 The electromagnetic radiation thought to be emitted by black holes is named after which scientist?

5 In what year was the electron microscope invented?

Answers on page 55

Puzzle

set by Alison Kiddle

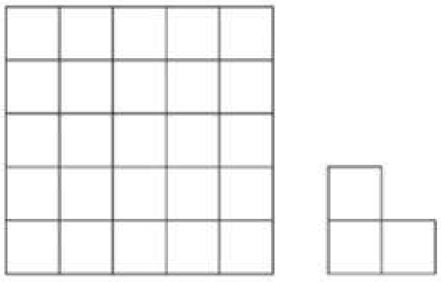
#193 Flush tiling

Bonnie is refitting her bathroom and her plumber has brought round some very peculiar tiles to cover the floor. Her bathroom is a 5×5 square and each tile is an L shape made up of three squares (see the diagram below).

Bonnie has realised it will be impossible to tile the whole bathroom without cutting tiles, as each tile covers three squares and 25 isn't a multiple of 3. When she points this out, however, her plumber says it is OK, as they will need to leave one square of floor space free for the toilet.

"Well, clearly I don't want the toilet in the middle of the room!" she says.

In which squares could the toilet be placed?



Solution next week

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Animal ace

What has been the most successful animal ever?

Clive Tiney
Haxby, North Yorkshire, UK
Firstly, we need to define what we mean by successful.

Humans are probably the most successful at colonising the planet, but we haven't been around for long when compared with the coelacanth, a type of fish that evolved more than 400 million years ago, or even monotremes, egg-laying mammals that arose around 200 million years ago. Such longevity might be a definition of success.

Brown rats have managed to colonise almost everywhere that humans have with very little effort, perhaps that is another definition. Of course, so have the bacteria in our guts.

> "Every animal is equally successful, as each has reached its own pinnacle from the last universal common ancestor"

Secondly, we should add the words "so far" to the question. Humans may be successful now, but our success has been so destructive to the planet's ecosystems that we may not be around for much longer.

Geoffrey Clark
Douglas, Isle of Man, UK
By many metrics, the most successful animal species is *Homo sapiens*: it has conquered the world and can fly around it in a matter of hours; it can live at the polar regions and the equator; plus, it is able to dive the depths of the sea, climb the highest mountains and even go to the moon.

Yet, in so doing, we have driven to extinction many species and will probably do more harm in the next 30 years or so because of the pollution we have created. We may even render Earth almost uninhabitable, at least for our own species. Is this success? Many dinosaur species lived millions of years longer than *H. sapiens* has so far managed.

As for individuals, a clam was found in the Arctic that was 507 years old, making it the oldest known animal except for colonial ones, such as corals. This may be counted as "successful", if sitting in one place in the sea for that time, just filtering nutrients without dying is a success. We might also consider the Bristlecone pine tree called Methuselah, in California, which is nearly 5000 years old and just stands there, getting older.

The tardigrade is another successful species, in that individuals can lie dormant for years, even in space, yet with a little water they will come back to life.

Bryn Glover
Kirkby Malzeard, North Yorkshire, UK
Another way to look at this question is to say that every animal is equally successful, as each represents its own equal pinnacle of development from the last universal common ancestor.

@GodthelpHendrik
via Twitter
Rats and house mice. These have expanded into every part of the world and nearly every environment, riding the coat-tails of humans.

@James_LeePT
via Twitter
House cats, for realising they can get humans to do everything for them, so they can just chill.

FRANS LEMMENS/ALAMY

Is it terminal for a spider to be thrown out of a window, asks one *New Scientist* reader

This week's new questions

Spider freefall **Do spiders survive if thrown from a height out of a window?** ***John Allen***, *Canterbury, Kent, UK*

Double trouble **If identical twin brothers are each potentially the father of the same child, is there a way to determine, genetically, which is the father?** ***Darryl Middleton***, *Melbourne, Australia*

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Paddle hand

My water aerobics instructor says to press my fingers together to increase resistance. The total surface area is the same with fingers open or closed, so why does it make a difference?

Stephen Johnson
Eugene, Oregon, US
The question of whether or not fingers should be pressed together to increase resistance, or drag, in water sports has been debated for decades. In a lifetime of competitive swimming, I first encountered this discussion in the early 1970s, although at that time there wasn't any real science on the subject.

Since 1979, there have been numerous experiments and simulations studying this topic. The current consensus is that drag is increased with the fingers held slightly apart compared with when the fingers are held together.

This is because water still isn't able to easily flow between the fingers, and the hand now acts as a slightly larger paddle. In addition, the hand is more relaxed in this position, making it easier for an athlete to maintain.

David Muir
Edinburgh, UK
Fluid dynamics can be counter-intuitive due to the effects of boundary layers.

A boundary layer is a region of fluid moving relative to a nearby surface. It is slowed by the fluid's viscosity and its adhesion to the surface.

If a swimmer or water aerobics participant wants to maximise the force generated by their hand moving through water, they should spread their fingers by a few millimetres – 10 degrees between each. Water won't flow smoothly between the fingers due to their boundary layers, which act like invisible webbing,

Tom Gauld

for New Scientist

DAMMIT ALAN! YOU'VE ALWAYS KNOWN I WAS A MARINE BIOLOGIST. DON'T MAKE ME CHOOSE BETWEEN OUR FRIENDSHIP AND MY STUDY OF YOUR FEEDING HABITS AND MIGRATORY PATTERNS!

thus increasing the effective size of the hand. Watch underwater video of elite swimmers to see their innate feel for the water with their slightly spread fingers.

Good golfers of the past knew that scratched and roughened golf balls flew further than perfect spheres long before they knew anything about fluid dynamics. The dimples on modern golf balls affect the boundary layer between ball and air, decreasing resistance and allowing for longer golf shots.

Nick Canning
Coleraine, County Londonderry, UK
Different shapes, even those presenting the same cross-sectional area perpendicular to their motion, will experience different resistance.

A hand with fingers pressed together in a flat plate experiences greater resistance than the five separate cylinders of spread fingers, due to the different patterns of turbulent flow they cause in the water, which dissipate energy differently. Greater energy loss means you have to work harder to maintain the same speed of your stroke.

> **"The question of whether or not fingers should be pressed together to increase drag in water sports is much debated"**

Think of the old, boxy shape of an early car compared to the round shape of a modern one. The old one experiences greater air resistance than the new one for the same area and speed, due to the different fluid flow patterns.

Steve Agar
Ninebanks, Northumberland, UK
Imagine trying to scoop up a handful of sand. You will end up holding more with your fingers closed than with them open.

Similarly, when you move your hand through water, you have to move some water out of its way, and the resistance you experience arises from the amount of water that obstructs your hand.

With fingers open, this amount of water is less, so the resistance experienced by the hand is less.

Pat French
Longdon-Upon-Tern, Shropshire, UK
When the fingers of your hand are spaced apart, they present a series of five curved fronts to the water as it flows between them. Even though the surface area may be similar, your individual fingers are more "aqua-dynamic" than the flat paddle that is formed by fingers held tightly together.

The looser formation means that water escapes, rather than providing the resistance against your arm's movement that drives you forward.

Looking at my own hand while pressing my fingers close together, I see that it tends to curve or dish as I squeeze. This might further impede the water flowing out of my palm and provide even more thrust. A water wheel fitted with cupped blades – a so-called Pelton wheel – is, similarly, more efficient at creating drag than a flat-bladed water wheel. ▮

Answers

Quick quiz #177
Answers

1 Andre Geim
2 Autotomy
3 Nitric acid
4 Stephen Hawking
5 1931

Quick crossword #120 *Answers*

ACROSS 1 The Matrix, **6** Mucus, **9** Riptide, **10** Lanolin, **11** Oxalis, **12** Info dump, **14** RAND, **15** Combustion, **18** Postpartum, **20** Stew, **23** Carboxyl, **24** Pseudo, **26** Avocado, **27** Gourami, **28** Trace, **29** Radiation

DOWN 1 Turboprop, **2** Explain, **3** Acidic, **4** Reef, **5** Xylene blue, **6** Mongoose, **7** Calculi, **8** Sunup, **13** Four-by-four, **16** Newtonian, **17** Up to date, **19** Sarcoma, **21** Tsunami, **22** Oscula, **23** Chart, **25** Aged

#192 Hand over
Solution

After the merger, there are 10 board members.

When two people meet and shake hands, there is one handshake. With three people, there are three handshakes, four people have six and so on, and with N people there are N(N−1)/2 handshakes. These are the so-called triangle numbers: 0, 1, 3, 6, 10, 15, 21 etc. The number of handshakes was reduced by a third, so we are looking for a triangle number that is three times another number, and we know that N is less than "a dozen or so". The only numbers that fit are N=10 (45 handshakes) and N=6 (15 handshakes). So, there are now 10 people on the board, of whom six refused to shake hands with each other.

Physics vs Mona Lisa

The wood and smile of the *Mona Lisa* fascinate scientists. Not wooden smile. Wood and smile. A new study in the *Journal of Cultural Heritage* reveals how researchers have spent 18 years exploring the wooden panel on which Leonardo da Vinci painted the *Mona Lisa*. Their quest: to find a "method to assess the hygro-mechanical behaviour of original panel paintings, through in situ non-invasive continuous monitoring".

Other scientists, bunches of them, have peered and peered at the little puzzle that rests atop that wood. Having seen everything else fail, some of them have been throwing their heaviest of tools – physics – at the art world's toughest problem. The issue, which dates from about the year 1507, is this: how do you explain the *Mona Lisa*'s smile? Some studies subject the woman to quantum mechanics and fluid dynamics.

She has had to deal with far more personal probes in the past. Doctors and biologists have churned out reports suggesting that Lisa had lost her front teeth, that she had Bell's palsy, that she had a swelling of the dorsum of the right hand suggestive of a subcutaneous lipoma or that she had other ailments, some nearly unmentionable.

Slobodan Prvanovic at the Institute of Physics in Belgrade, Serbia, applied more conceptual methods, stepping up with a study called "Mona Lisa – Ineffable smile of quantum mechanics". Prvanovic explains that "the mysterious state Mona Lisa is in" is a coherent superposition of two quantum states: cheerfulness and sadness. The application of these concepts to this question is so new that many physics textbooks don't mention it.

By Feedback's estimation, the most moving study is "The turbulent structure of *sfumato* within Mona Lisa" by Diogo Queiros-Conde, a physicist at Mines ParisTech, France.

Sfumato, Queiros-Conde explains, is "a painting technique using thin layers of color that are superimposed and intermixed in order to create effects of perspective, depth and volume". Queiros-Conde disassembles the *Mona Lisa*'s sfumato using some of the tools of fluid dynamics. He begins with Andrey Kolmogorov's technique for analysing the local structure of turbulence in incompressible viscous fluid for very large Reynolds numbers. This by itself isn't powerful enough to finish the job, so Queiros-Conde caps it with a new geometrical approach of his own devising. Called entropic skins geometry, this pertains to the statistics and geometry of fully developed turbulent flows. The details are nothing if not engrossing.

The highlight is Queiros-Conde's discovery of something that 500 years of art scholars seem to have missed. On the final page of his study, he writes: "I advise the reader to pay attention to the luminous form just under Mona Lisa's left shoulder." The reward is ample. There, he writes, "one should recognize a form that can be interpreted as a human skull".

Maths vs Mona Lisa

Some scientists feel that maths, not physics, is the heaviest of assault weapons. They deploy it when handed some problem that has defied solution and maybe made people cry. The *Mona Lisa* brings many such problems.

Alessia Amelio at the University of Calabria, Italy, went on a mental adventure ride, collecting some of the mathematical methods that people have taken to war against the *Mona Lisa*'s mystery. She describes part of that armoury in a paper called "Exploring Leonardo da Vinci's Mona Lisa by visual computing: A review", delivered in Pisa in 2019. Here are some of the methods: computed Mahalanobis distance; inverse Fourier transform; bi-scatter plot pixel counting; genetic algorithms; and ant colony optimisation, to name just a few.

The study tells at length and depth about attempts to calculate estimates of the age of the woman in the artwork, whose painted form has apparently (but maybe not actually, as you will, uh, see in a moment) been staring strangers in the eye for more than half a millennium now.

Still, the problem remains unsolved. The *Mona Lisa* continues to braintease. The situation can be embarrassing to almost anyone, if they have read a study by Gernot Horstmann and Sebastian Loth at Bielefeld University, Germany, called "The Mona Lisa illusion – Scientists see her looking at them though she isn't". Reader Dany Adams, herself a biologist, brought it to Feedback's attention.

The study tries to explain what is known as "the *Mona Lisa* effect". You perceive the painted eyes as gazing directly at you, no matter where you stand. Move left or right, Lisa is still looking at you.

Horstmann and Loth had volunteers gaze at zoomed-in portions of the image, rather than at the full original. Viewers would, for example, see the painting with some of its left side removed, so that Lisa's face was at the left of the frame, rather than the centre. The researchers performed careful measurements. They pondered their data. They concluded that the *Mona Lisa* effect happens when people see the complete painting, but not so much when they see only a portion.

"We demonstrated," they boast, "that Mona Lisa gazes to her left-hand side from about 35.5 cm inside pictorial space and 15.4° to the viewer's right-hand side in real space... There is no doubt about the existence of the Mona Lisa effect – it just does not occur with Mona Lisa herself."

Marc Abrahams

Twisteddoodles *for New Scientist*

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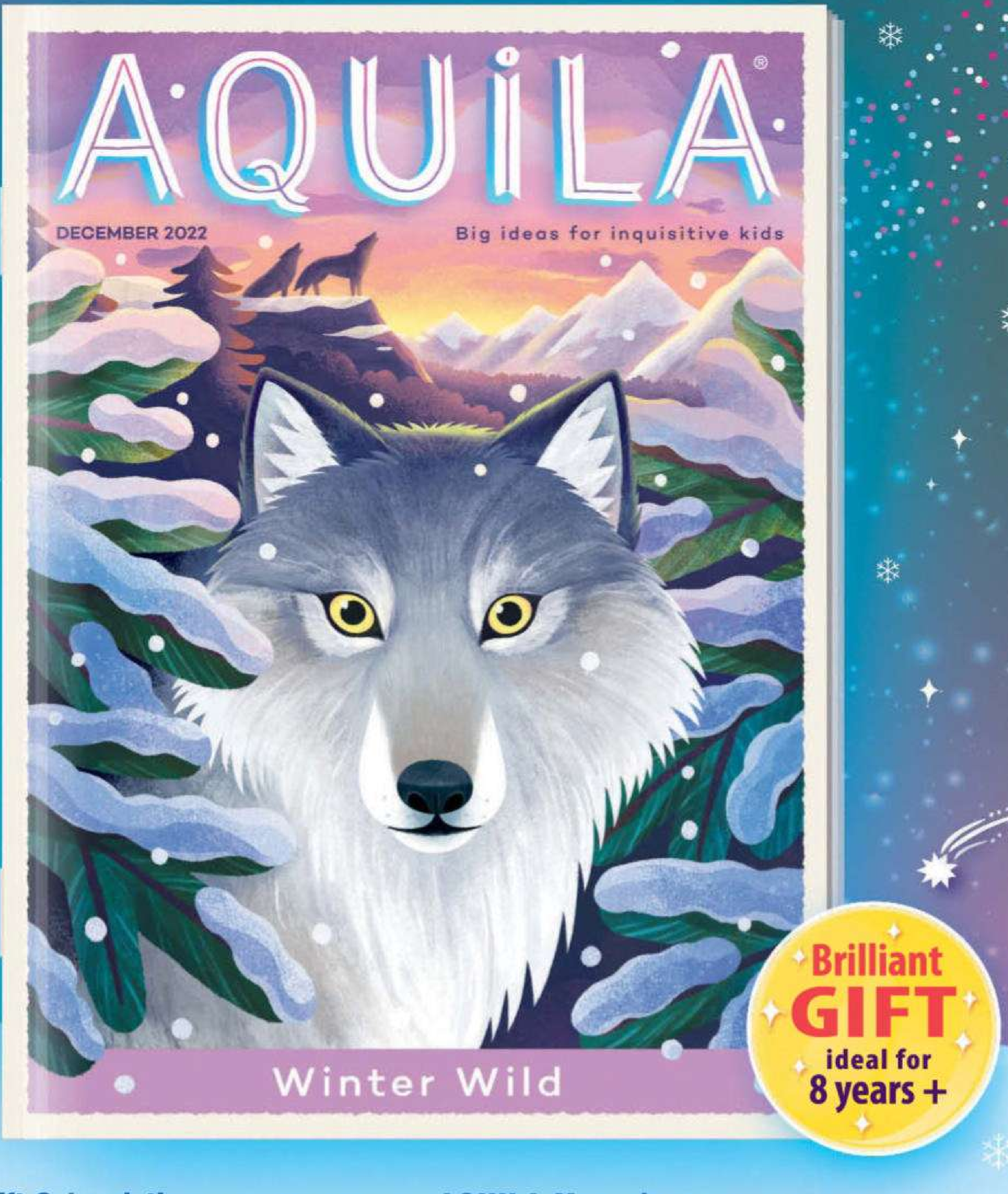
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